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PB-291 371

Feedlot Runoff Control Research Program

Illinois Univ at Urbana-Champaign

Prepared for

Illinois Inst for Environmental Quality, Chicago

May 76

PB 291371

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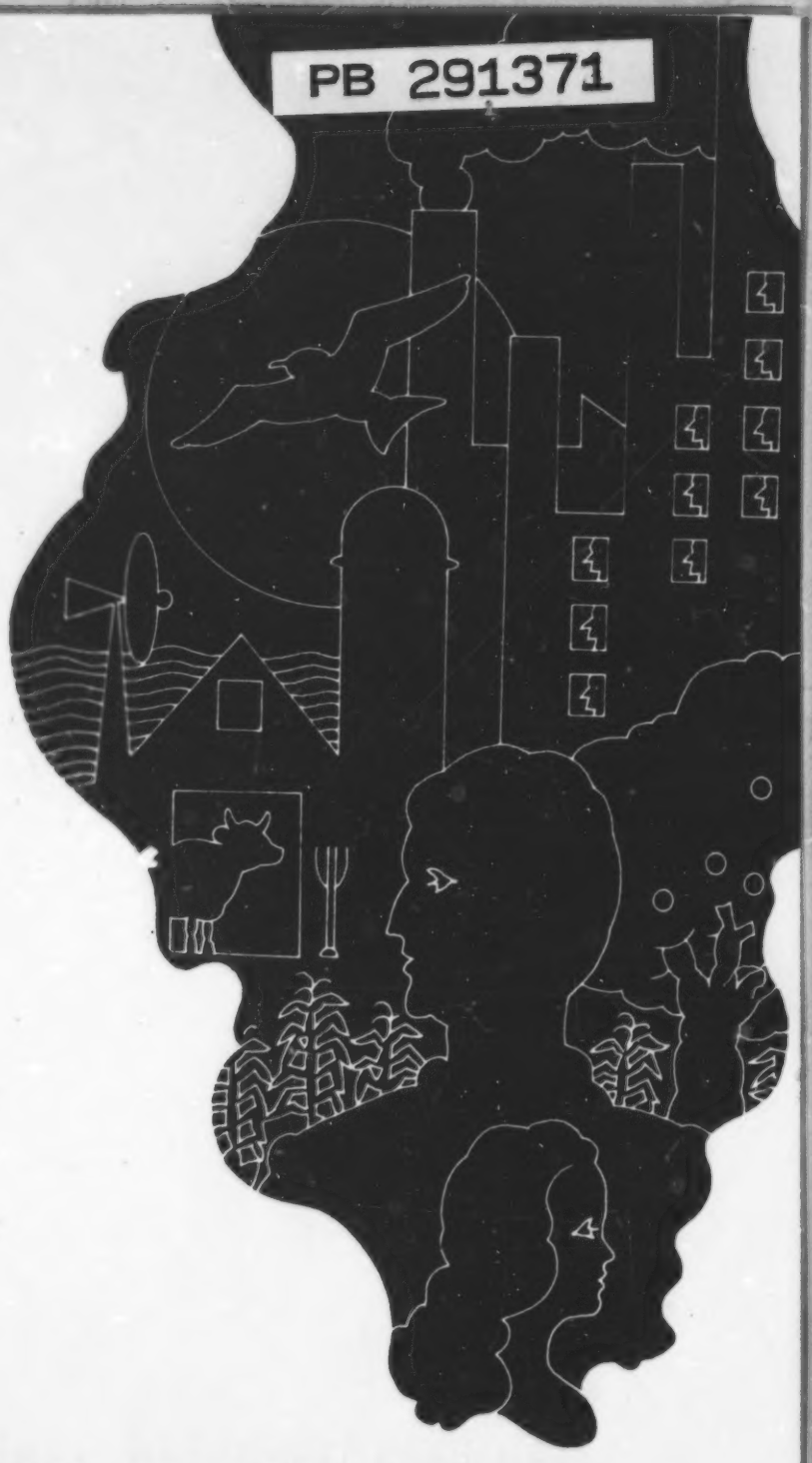

FEEDLOT RUNOFF CONTROL RESEARCH PROGRAM

IIEQ Document No. 76/08

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SPRINGFIELD, VA. 22161

BIBLIOGRAPHIC DATA SHEET	1. Report No. IIEQ 76/08	2.	3. Recipient's Accession No. PB291371
4. Title and Subtitle Feedlot Runoff control Research Program, Final Report			5. Report Date 5/1976 6.
7. Author(s) Agricultural Engineering Department			8. Performing Organization Rept. No.
9. Performing Organization Name and Address Agricultural Engineering Department University of Illinois at Urban-Champaign Urbana, Ill.			10. Project/Task/Work Unit No. 20.062 11. Contract/Grant No.
12. Sponsoring Organization Name and Address Ill. Institute for Environmental Quality 309 W. Washington St., Chicago, IL 60606			13. Type of Report & Period Covered Final 14.

15. Supplementary Notes

16. Abstracts

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17. Key Words and Document Analysis. 17a. Descriptors

Animal Husbundary

17b. Identifiers/Open-Ended Terms

Animal Wastes - Management
Animal Waste - Runoff

17c. COSATI Field/Group 06 Biochemistry 13B Civil Engineering

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Unlimited distribution sponsored by U.S. EPA	UNCLASSIFIED	62
	20. Security Class (This Page) UNCLASSIFIED	22. Price A04-A01

FORM NTIS-35 (REV. 3-72) THIS FORM MAY BE REPRODUCED USCOMM-DC 14952-P72

FEEDLOT RUNOFF CONTROL RESEARCH PROGRAM

Final Report

Project No. 20.062

IIEQ Doc. No. 76/08

AGRICULTURAL ENGINEERING DEPARTMENT
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

in cooperation with

STATE OF ILLINOIS
INSTITUTE FOR ENVIRONMENTAL QUALITY

MAY, 1976

NOTE

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Printed by Authority of the State of Illinois

Date printed: May, 1976

Quantity printed: 300

This publication has been cataloged as follows:

Illinois. University at Urbana - Champaign. Agricultural Engineering Department.

Feedlot runoff control research program: final report. Chicago, Illinois Institute for Environmental Quality, 1976.

55 p. (IIEQ Doc. No. 76/08)

1. Animal wastes - Management. 2. Animal wastes - Management - Land disposal. 3. Animal waste runoff. 4. Water pollution control - Rural. I. Illinois Institute for Environmental Quality. II. Tital.

IIEQ Information Center

Illinois Institute for Environmental Quality
309 West Washington Street
Chicago, Illinois 60606

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PREFACE

This is the final report for a feedlot runoff control research project funded by the Illinois Institute for Environmental Quality. Additional support was also received from the Illinois Agricultural Experiment Station, and the Rockefeller Foundation. The project was initiated in March, 1974, and continued through June, 1975. This report summarizes the results of the data collection and observation conducted during the study. It is intended to provide information which can be used in planning better systems of runoff control and improving those currently in use.

We gratefully acknowledge the assistance and cooperation of the livestock producers involved in this study: Russell Flanders, Elburn; Eldon Gould, Elburn; Kenneth Bartels, Elgin; Ron Lawfer, Stockton; Dick Pilchard, Farmer City: Vernon Veatch, Roberts; and Ryan Veatch, Thawville.

FEEDLOT RUNOFF CONTROL RESEARCH PROGRAM
Final Report

Elbert C. Dickey and Dale H. Vanderholm

Six commercial livestock operations in northern and central Illinois cooperated in the feedlot runoff control research program. Begun in 1974, this monitoring project was designed to evaluate installed feedlot runoff control systems in terms of their management requirements, operator acceptability, and their overall effectiveness in preventing water pollution. The systems monitored were controlling runoff from beef, dairy, and swine operations. Several of the systems were designed by the Soil Conservation Service. All six operations serve for demonstration as well as for data collection and are frequently visited by livestock producer tour groups, individuals seeking firsthand information on the operation and performance of the systems, and groups interested in water pollution control.

The design of runoff control systems in Illinois and most other states has evolved to the conventional system illustrated in Figure 1. This system consists of facilities for clean water diversion where necessary, a collection channel, settling basin, runoff holding pond, and pumping equipment for dewatering the holding pond. Capacities, shapes, and construction materials for each component may vary a great deal, but the same basic components are normally present in each installation.

For locations of the demonstration-research sites, see Figure 2. Table 1 summarizes the following information describing the six livestock operations and runoff control systems studied.

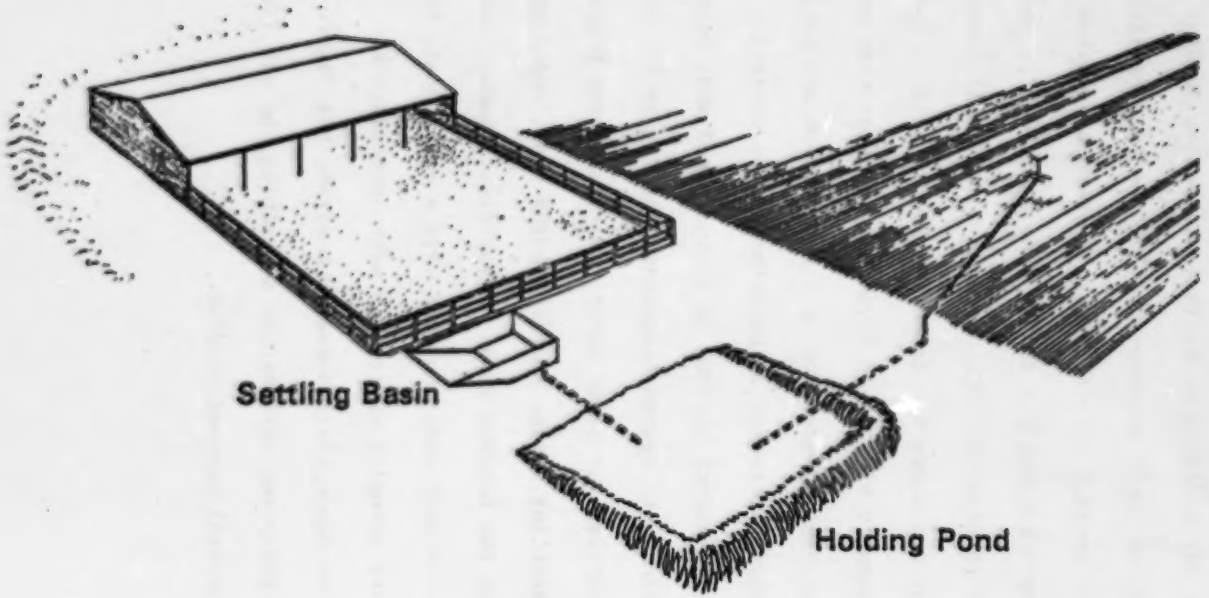

Figure 1. Typical configuration of a runoff control system for open feedlots.

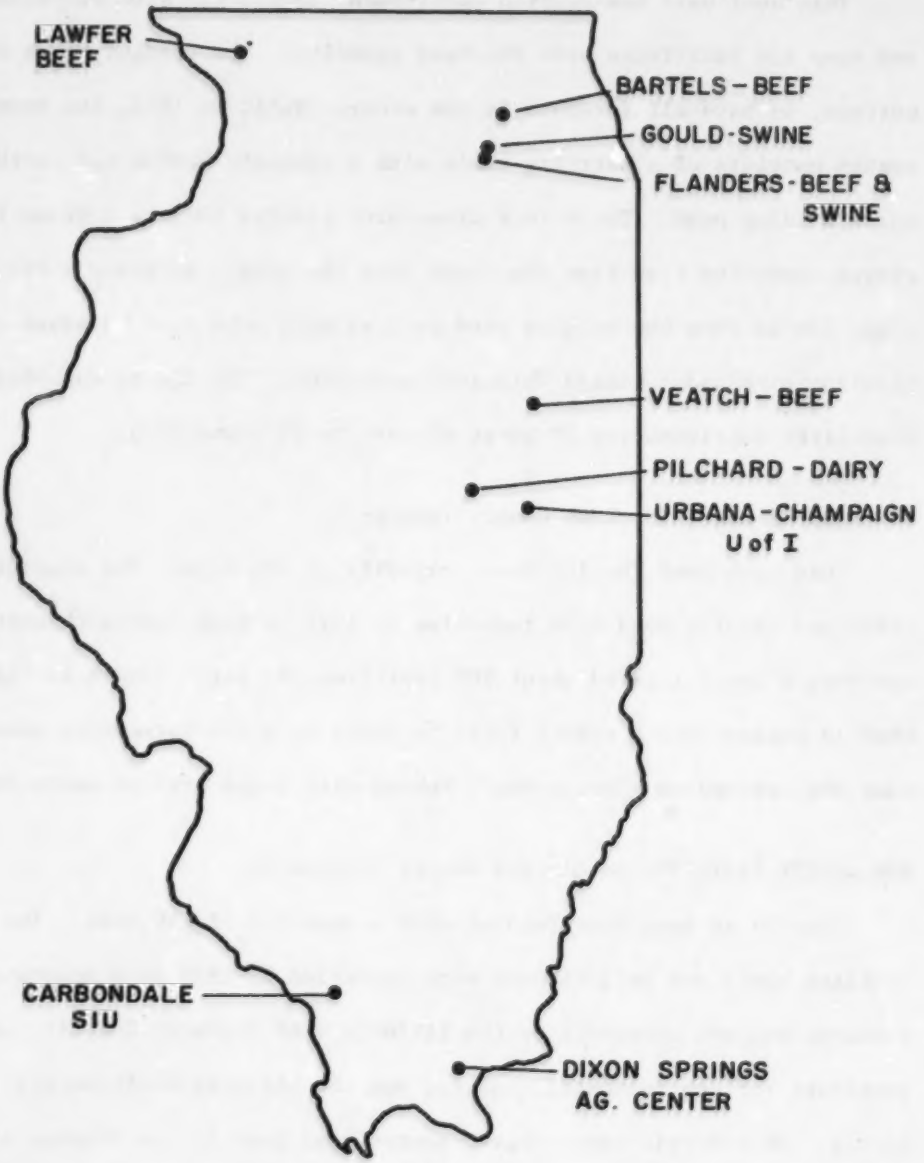

Figure 2. Locations of demonstration - research sites for feedlot runoff control systems.

VERNON AND RYAN VEATCH FACILITY, Ford County (System 1)

This beef unit has covered confinement facilities with 425-head capacity and open lot facilities with 700-head capacity. The feedlot has a concrete surface, as have all feedlots in the study. Built in 1972, the runoff control system consists of a settling basin with a concrete bottom and earth sides, and a holding pond. Two 6-inch pipes with slotted 30-gallon drums for risers carry the flow from the basin into the pond. By using a PTO-driven pump, liquid from the holding pond is irrigated onto corn by means of portable aluminum pipe and a single "big-gun" sprinkler. The liquid supplied the fertilizer nutrients for 20 acres of corn in 1974 and 1975.

KEN BARTELS FACILITY, Kane County (System 2)

This open beef feedlot has a capacity of 300 head. The concrete settling basin and holding pond were installed in 1972 to keep livestock wastes from reaching a creek located about 100 feet from the lot. Liquid in the holding pond is pumped onto a nearby field by means of a low-horsepower submersible pump and corrugated plastic drain tubing with holes drilled every few inches.

RON LAWFER FACILITY, Jo Daviess County (System 3)

This is an open beef feedlot with a capacity of 150 head. The concrete settling basin and holding pond were installed in 1973 as a demonstration-research project sponsored by the Illinois Beef Industry Council, the Illinois Institute for Environmental Quality, and the Illinois Environmental Protection Agency. An electric-motor-driven centrifugal pump is coordinated with a sprinkler irrigation system to apply the holding-pond liquid onto a terraced field. To help separate liquids and solids at the basin, an expanded steel screen has been placed in the basin with a corrugated metal riser on the back of the screen.

RUSSELL FLANDERS FACILITY, Kane County (System 4)

This open beef feedlot has a capacity of 300 head. The feedlot is located next to a road ditch, which required periodic cleaning to remove the manure carried in by runoff. In 1972 Mr. Flanders installed the runoff control system--a concrete settling basin and a holding pond--to alleviate the problem. The holding pond also provides additional storage for wastes from confinement hog production facilities; excess effluent is pumped on adjacent cropland. As with the systems described earlier, solids from the settling basin are removed with conventional solids-handling equipment and spread onto cropland.

ELDON GOULD FACILITY, Kane County (System 5)

This confinement hog production unit uses open, concrete-slab feeding floors. The capacity is 1,200 hogs. Installed in 1973, the runoff control system consists of two concrete settling basins and a holding pond. An expanded metal screen, similar to that used in the Lawfer settling basin, has recently been added to one of Gould's basins to help separate solids and liquid. A tank wagon has proved effective in removing the semi-solid material that collects in the basin, although a front-end loader can be used if the new screen proves effective in dewatering the solids. The liquid from the holding pond is pumped by a small submersible pump suspended from a float onto the nearby fields through flexible, perforated plastic pipe.

DICK PILCHARD FACILITY, Piatt County (System 6)

This is an open dairy lot with a capacity of 70 cows. Runoff control and manure storage facilities were built in 1973. Both milkhouse and milking parlor wastes go into the runoff control system. The unique feature of the Pilchard facility is that liquid from the concrete settling basin is pumped

into the holding pond. Because natural slope in the area is low, a gravity-flow system will not work, and the liquid must be pumped. Expanded steel screens augment the settling process in separating the solids from the liquid in the basin before pumping into the holding pond.

Table 1. Characteristics of the Feedlots Where Water Quality in Runoff Holding Ponds Was Studied

Feedlot	Operation	Lot area (ft^2)	Lot capacity (number of animals)
1	Beef	34,850	700
2	Beef	15,000	300
3	Beef	6,400	150
4	Beef[a]	15,000	300
5	Swine	23,100	1,200
6	Dairy[b]	10,000	70

[a]Holding Pond 4 also receives anaerobic swine manure pit overflow.
[b]Milking parlor wastes go into the runoff control system.

RAINFALL-RUNOFF AND EVAPORATION

Rainfall and runoff data were collected at all locations. Feedlot 1 was equipped with a recording rain gauge, a holding pond stage recorder, and a Class-A evaporation pan. Non-recording rain gauges and staff gauges for holding-pond stage readings were used at the other feedlots.

Holding-pond stage levels and rainfall measurements were used to calculate the rainfall-runoff relationship. The data from the five feedlots without recording equipment did not prove adequate for inclusion, but data on Feedlot 1 were satisfactory. The rainfall-runoff relationship for Feedlot 1 is shown in Figure 3. The rainfall-runoff relationship found in this study compares quite favorably with the results of Swanson et al. (1971), although their data were

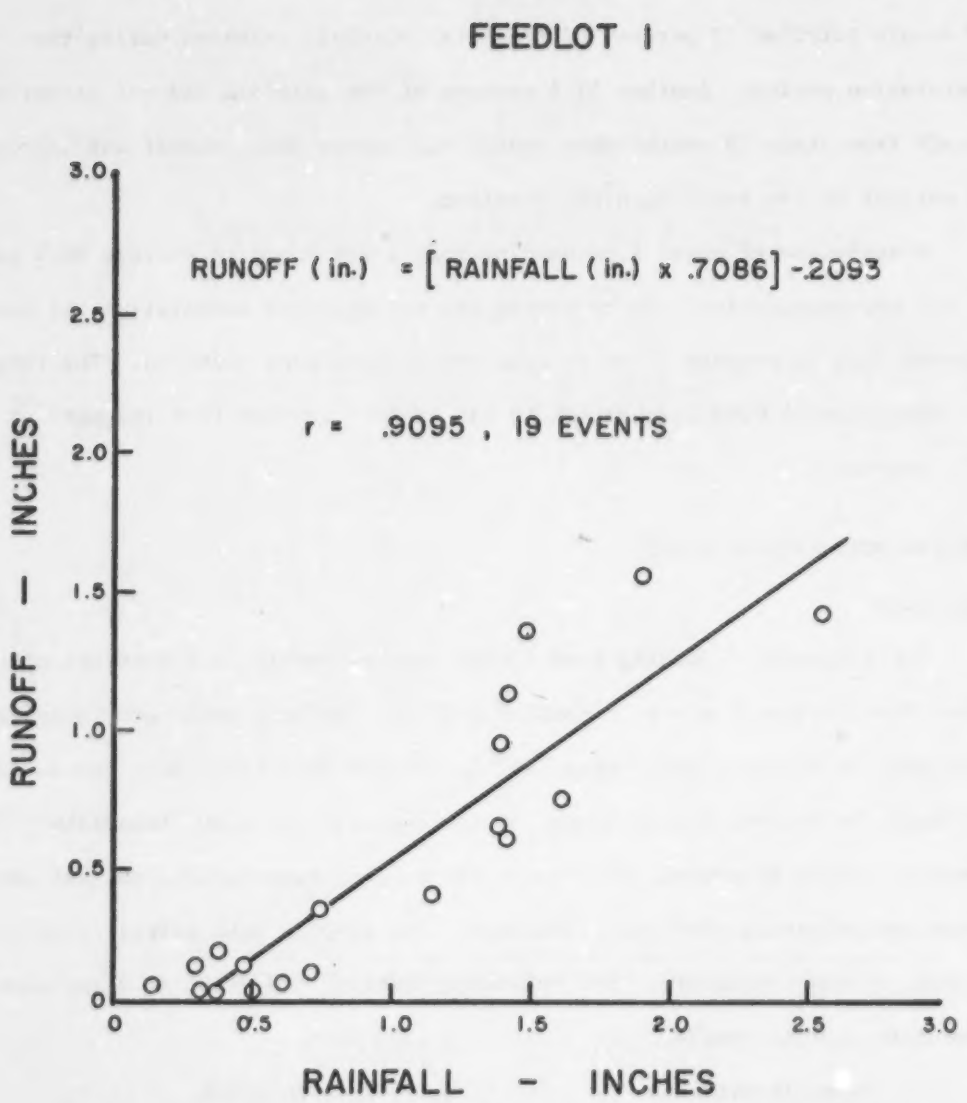

Figure 3. Rainfall-runoff relationship for a paved lot (Feedlot 1).

for earthen rather than paved lots. In addition to 19 rainfall events during the observation period where runoff occurred, there were also 20 rainfall events ranging from 0.1 inch to 0.43 inch from which no runoff occurred. These 20 events totalled 17 percent of the total rainfall received during the observation period. Another 17.6 percent of the rainfall did not appear as runoff from those 19 events when runoff did occur; thus, runoff was approximately 65 percent of the total rainfall received.

Evaporation of water from Holding Pond 1 was found to average 88.4 percent of the pan evaporation. In computing the holding-pond evaporation, it was assumed that no seepage of water from the holding pond occurred. The range in percentage of pond evaporation to pan evaporation was from 108 percent to 64.7 percent.

HOLDING POND WATER QUALITY

Procedure

The contents of Holding Pond 1 were sampled weekly, and contents of the other five holding ponds were sampled monthly. Using a pond water sampler developed by Mitchell and Dickey (1973), samples were taken near the surface and near the bottom, approximately at the center of the pond. Immediately following sampling, field measurements of dissolved oxygen, temperature, pH, and oxidation-reduction potential (ORP) were obtained. The samples were refrigerated upon arrival at the laboratory. The following chemical and physical measurements were made on each sample.

- ammonia nitrogen
- total Kjeldahl nitrogen
- nitrate + nitrite nitrogen
- total phosphorus
- total potassium
- total sodium
- chloride
- conductivity
- chemical oxygen demand
- total solids
- total suspended solids

All analyses were made following procedures outlined in Standard Methods (1971), except that ammonia and nitrate + nitrite nitrogen were determined by the method described by Bremner and Keeney (1965). Although some measurements are not discussed in detail, their importance in explaining trends observed will be noted.

Nitrogen

Ammonia nitrogen, Kjeldahl nitrogen, and nitrate + nitrite nitrogen concentrations were measured in each holding-pond sample. Since concentrations of nitrate + nitrite nitrogen in the ponds studied were often at or near zero concentration, Kjeldahl nitrogen can be used as the measure of total nitrogen present.

Figure 4 shows the seasonal variation in the ammonia nitrogen and Kjeldahl nitrogen in Holding Pond 1 during 1974. Near the end of June, 1974, Holding Pond 1 was pumped dry and remained dry throughout most of July. In 1975, Holding Pond 1 exhibited a similar late-summer drop in nitrogen as shown in Figure 5 even though the pond was not pumped dry in 1975. The trends exhibited in Figures 4, 5, and 6 were observed in all the holding ponds under study. During the spring months of March, April, and May, ammonia nitrogen and Kjeldahl nitrogen were at peak concentrations. As water temperature began to increase, nitrogen concentration began to decrease and continued to decrease into late summer. This decrease in nitrogen was largely attributed to volatilization of ammonia from the pond surface, a process that has been well described by Koelliker and Miner (1973). While in some instances, denitrification could account for some of the nitrogen decrease, the initial step in denitrification is the reduction of oxidized nitrogen such as nitrate. Measurable concentrations of oxidized nitrogen were not observed in the ponds

under study; therefore, denitrification probably is of little or no importance in the nitrogen cycle of anaerobic holding ponds.

The nitrogen concentration increase observed in late fall was largely due to the increased number of rainfall-runoff events. Also, the decrease in pond water temperature as fall approaches causes a decline in the microbial activity. With lowered microbial activity, nitrogen entering the pond was not assimilated or decomposed as rapidly, and the total nitrogen concentration increased without a corresponding increase in ammonia loss.

If the farmer or operator is trying to gain the maximum nitrogen benefit for crops from the holding-pond water, the season the water is applied to the land is quite important. According to Figure 4, approximately 85 pounds of nitrogen would be applied with each acre-inch of water if the irrigation occurred in mid-April. If the irrigation occurred near the end of June only 35 pounds of nitrogen would be applied with each acre-inch of irrigated water.

Besides the seasonal nitrogen variation in holding ponds, there are also large variations among different systems (Figure 7). Nitrogen differences between beef and swine operations can largely be explained by the basic differences between the animals as well as their rations. Differences among beef facilities are a function of lot management and animal concentration on the feedlot. Lot management refers in part to the amount of manure allowed to build up on the lot surface before cleaning. A system with weekly lot scrapings would contribute less nutrients to the holding pond than a system that uses a monthly lot scraping. Studies by Gilbertson et al. (1971), have shown that, as the number of animals on the lot increases and no change in lot management occurs, the amount of nutrients entering the holding pond when runoff occurs also increases.

Figure 7 also shows that nitrogen concentration varies year-to-year on each system. This variation may be the result of differences in

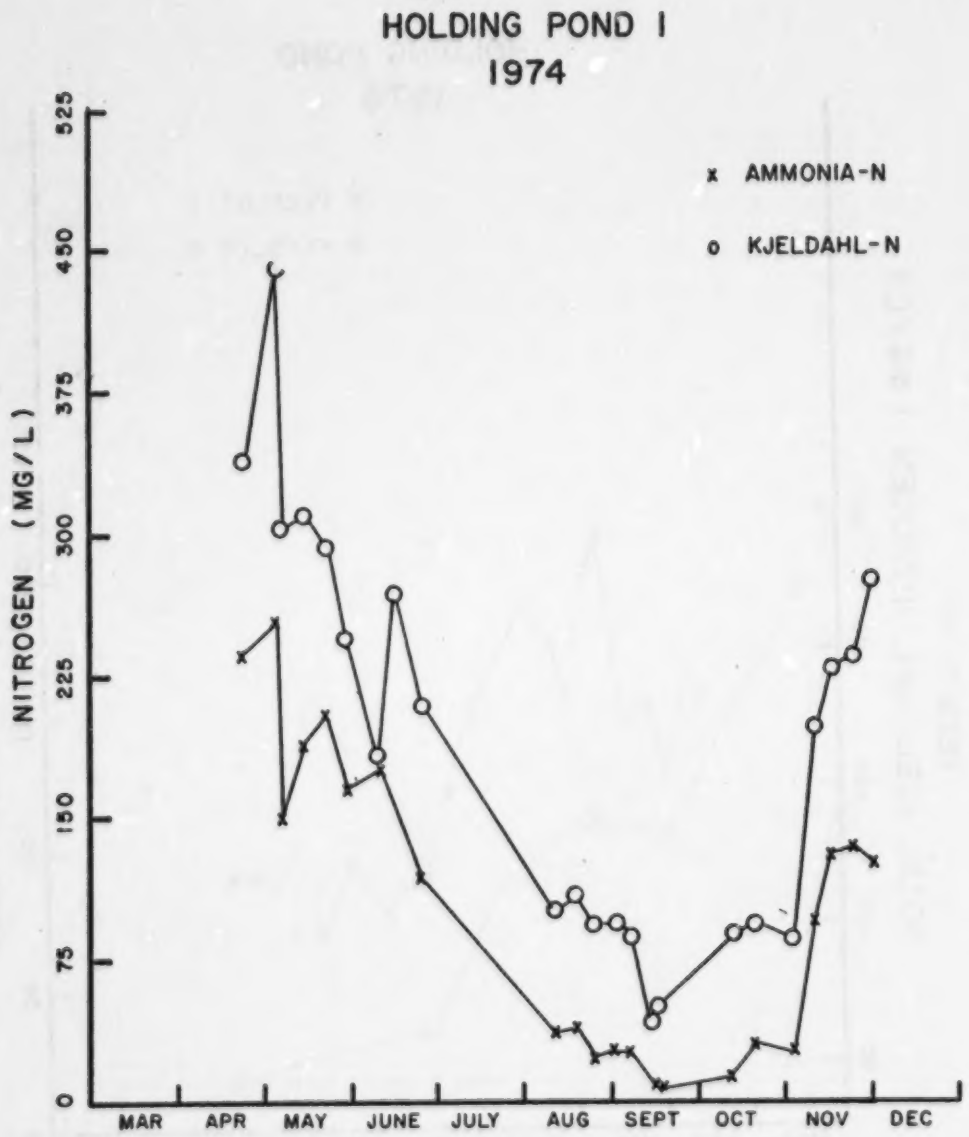

Figure 4. Seasonal variation of a ammonia and Kjeldahl nitrogen in holding-pond water.

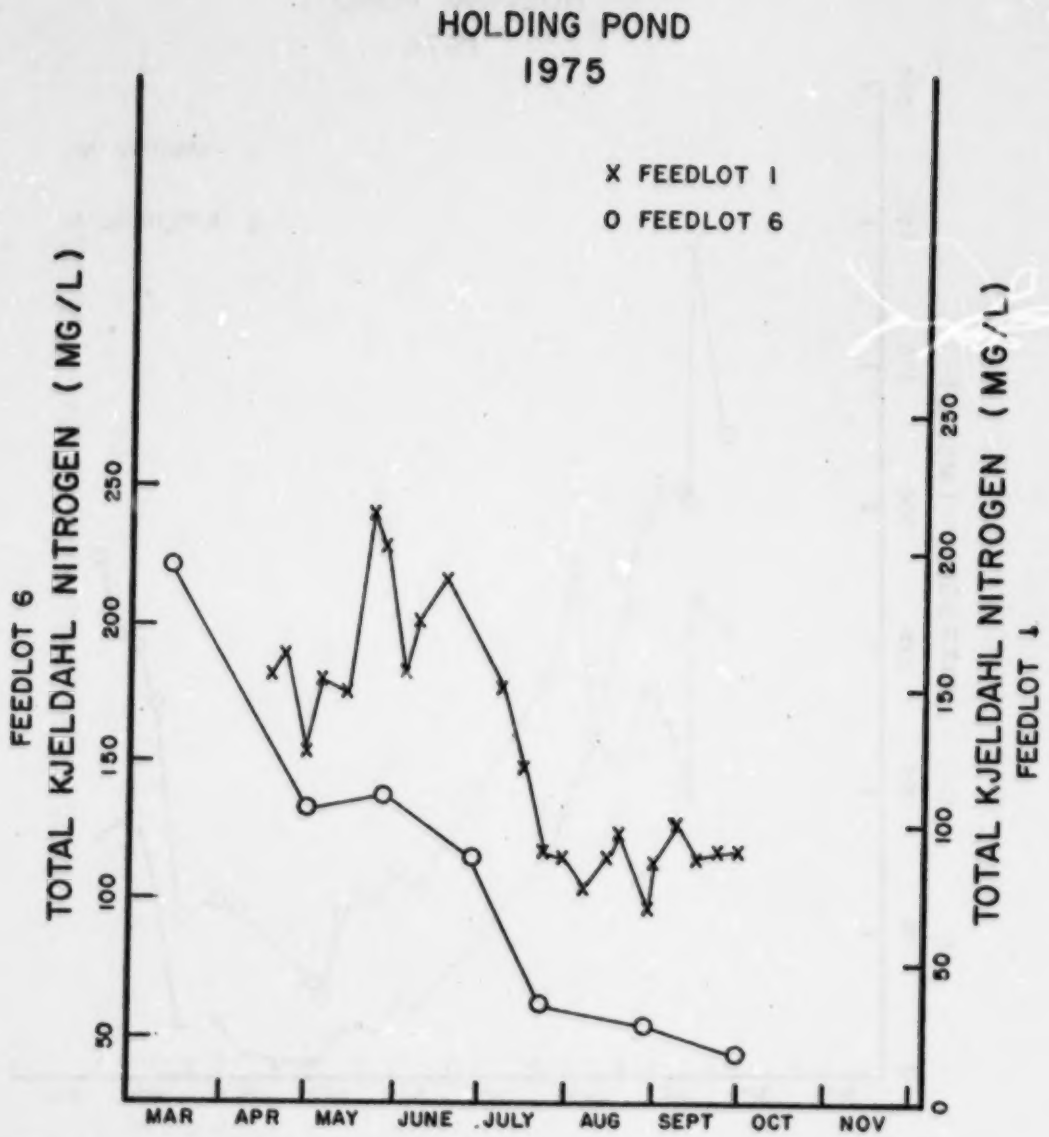

Figure 5. Seasonal variation of Kjeldahl nitrogen in Holding Ponds 1 and 6 during 1975.

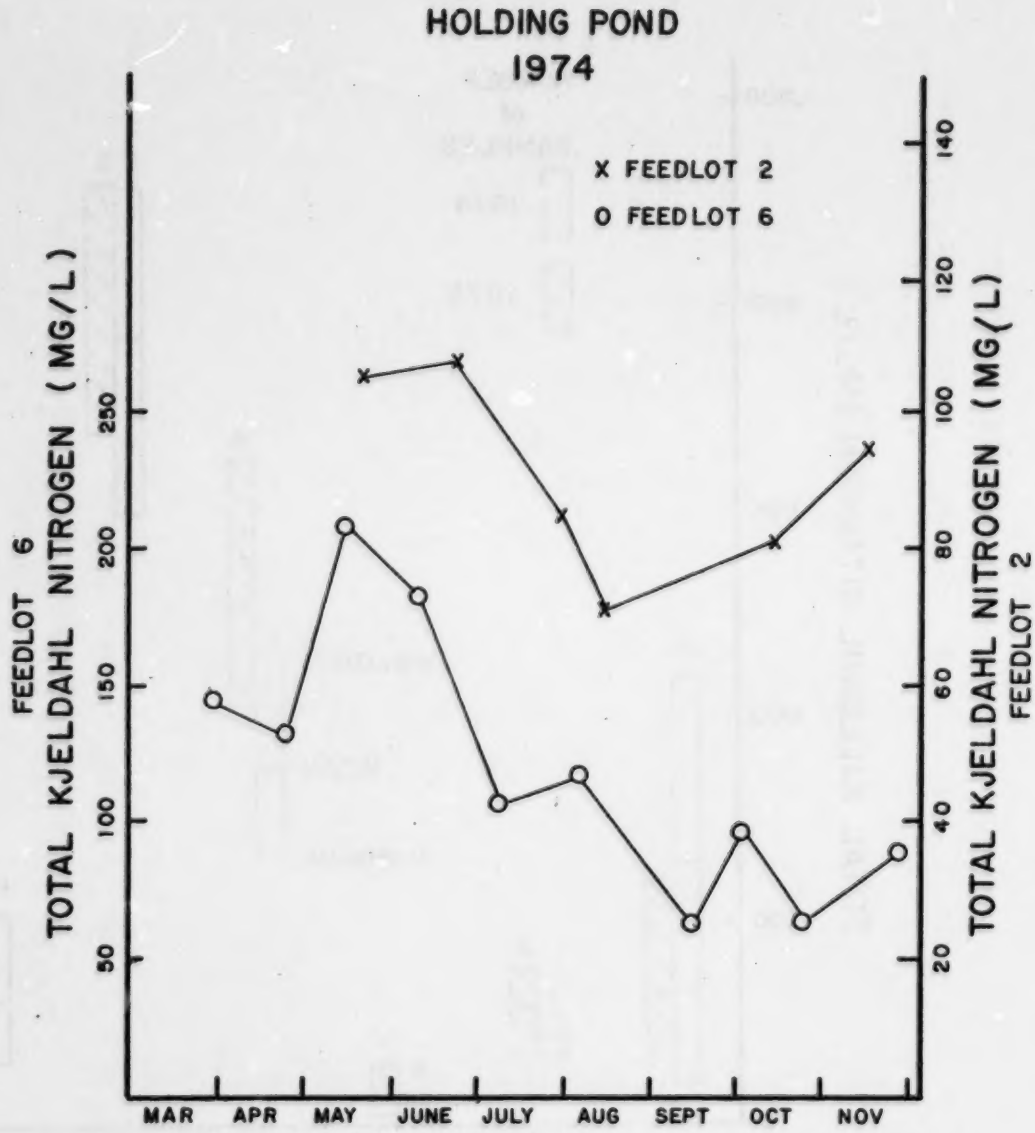

Figure 6. Seasonal variation of Kjeldahl nitrogen in Holding Ponds 2 and 6 during 1974.

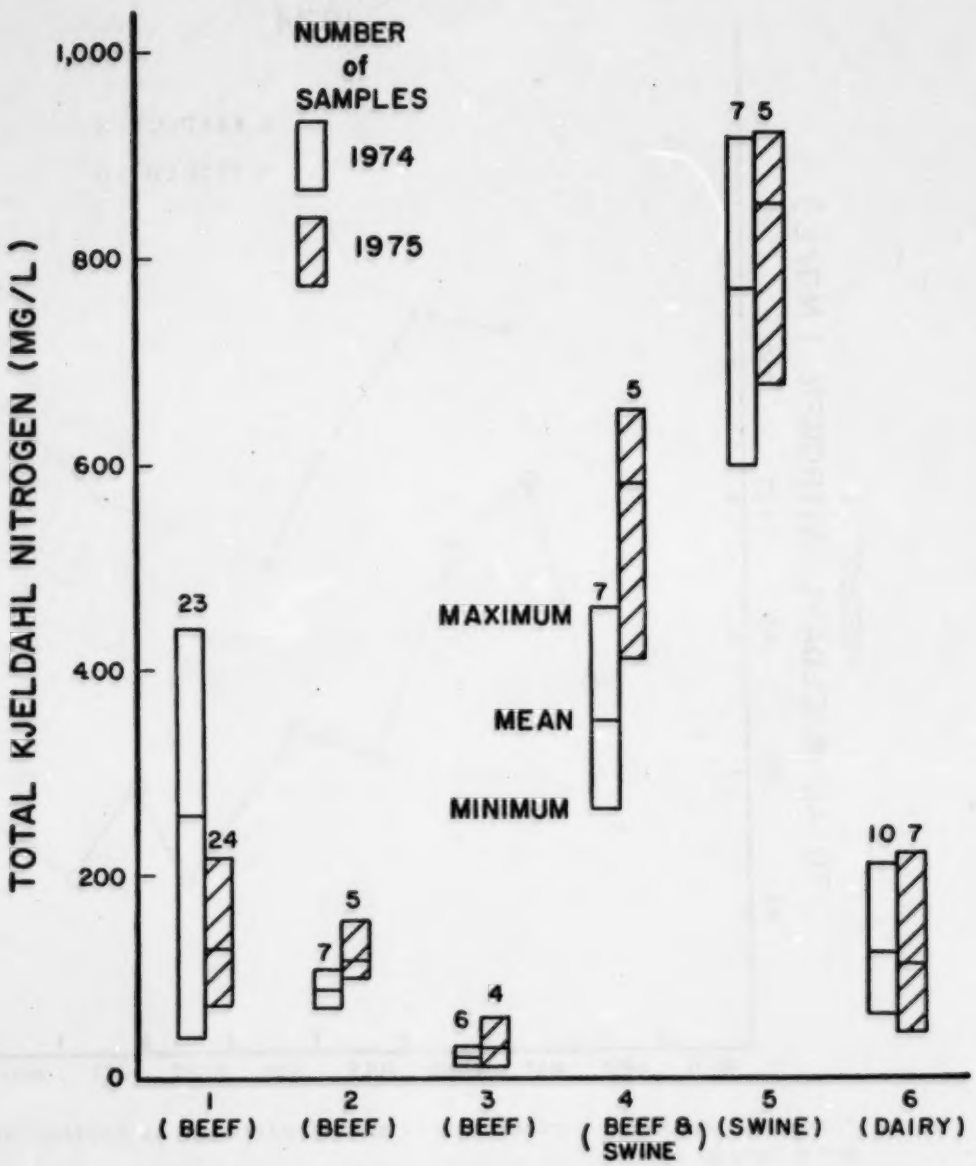

Figure 7. Variation of nitrogen within a runoff holding pond among different feedlots and between years.

annual rainfall and temperature, changes in animal population of the system, changes in lot management, or a combination of these and other factors. Reducing the number of animals by about one-half during a major portion of the 1975 sampling period is thought to be the reason for the decrease in nitrogen concentration from 1974 to 1975 in Holding Pond 1. A similar reduction in animal numbers occurred in Feedlot 2, but the nitrogen concentration in Holding Pond 2 was generally higher in 1975; this increase in nitrogen is attributed to the fact that the operator simply did not clean the lot as often in 1975 as in 1974. With a reduced level of lot management, manure accumulated on the feedlot surface, raising the nitrogen concentration in the runoff water. The animal population in Feedlot 3 was about the same for the 1974 and 1975 observation periods. During the 1975 observation period, however, the feedlot was not cleaned which increased the mean nitrogen concentration in Holding Pond 3 in 1975.

Table 2 lists the percent of total nitrogen in the ammonia form. Differences among the systems are large and are due to differences in animal species, population, rations, and in rainfall and lot management. Having a high percentage of the nitrogen in the ammonia form has both advantages and disadvantages. Nitrogen applied to a crop in the ammonia form becomes immediately available for use by the crop, while nitrogen in an organic form must undergo biological decomposition before becoming available in inorganic form. However, ammonia nitrogen can be lost through volatilization to the atmosphere. Volatilization can be significant, especially if the holding-pond water has a pH greater than 7.0 and is applied to the crop through a spray nozzle. In general, the pH of holding-pond water near the surface was continually above 7.0 during the months of June, July, August, and September.

Table 2. Average Percent of Kjeldahl Nitrogen in Holding Pond Water in Ammonia Nitrogen Form

Farm	Operation	Average Percent 1974	1975
1	Beef	44	43
2	Beef	50	42
3	Beef	29	10
4	Beef & Swine	85	76
5	Swine	74	68
6	Dairy	41	32

Phosphorus and Potassium

The seasonal variation of phosphorus and potassium concentration is shown in Figures 8 and 9 for Holding Pond 1, Figure 10 for Holding Pond 2, and Figure 11 for Holding Pond 6. Phosphorus did not exhibit as strong a seasonal trend as nitrogen, but a decrease in the phosphorus concentration occurred during June, July, and August. This decrease was observed in all holding ponds studied. The phosphorus decrease was probably due to precipitation of insoluble phosphorus compounds, as outlined by Booram et al. (1973). Analysis of sediment material (Table 5) from Holding Pond 1 showed that the amount of phosphorus in the sediment was more than 100 times the average amount measured in the holding-pond water during 1974.

The potassium concentration showed a slight but significant increase throughout the summer, (Figures 8 through 11), partly the result of water evaporation. The large increase in potassium in late fall is probably caused by the increased number of rainfall-runoff events.

Maximum, minimum, and average concentrations are shown for phosphorus in Figure 12 and for potassium in Figure 13. Differences between beef and

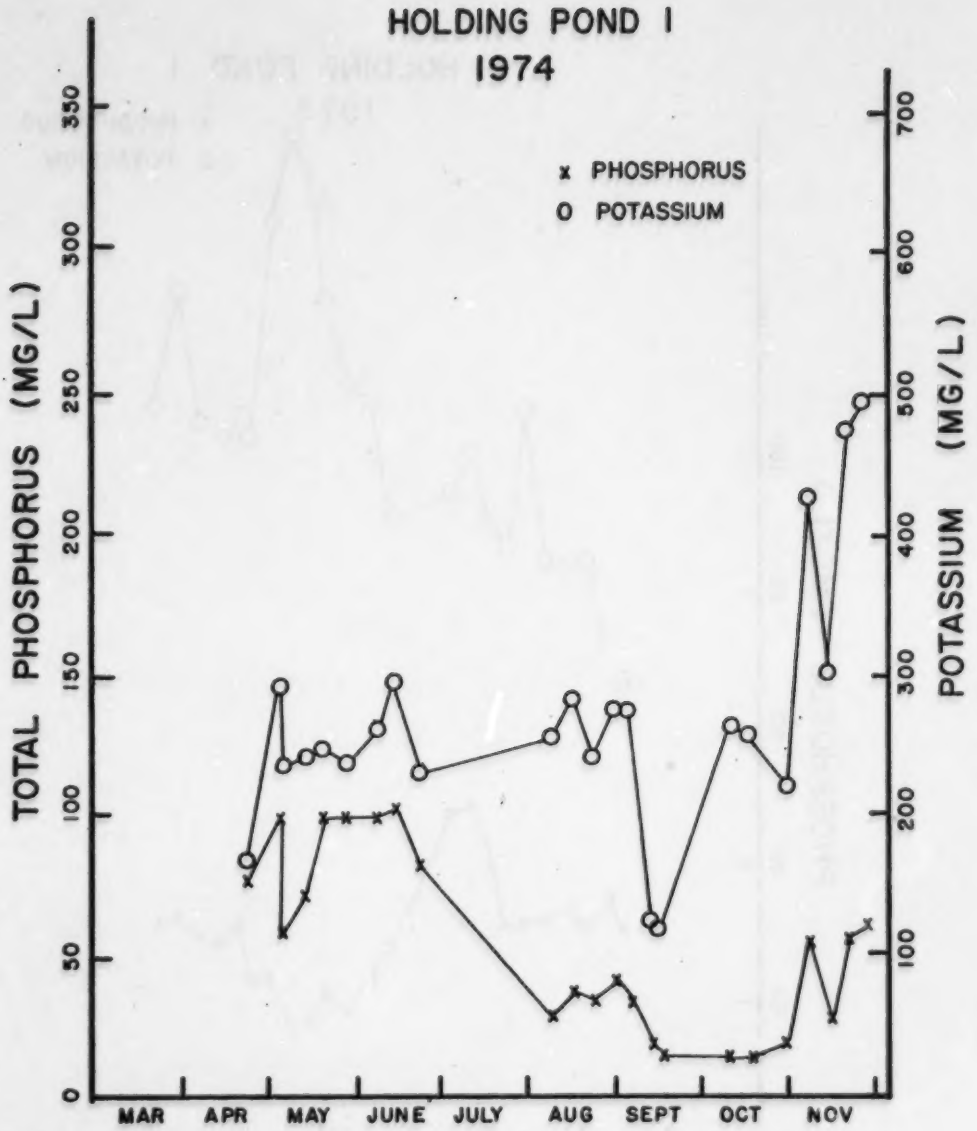

Figure 8. Seasonal changes in phosphorus and potassium concentrations in Holding Pond 1 during 1974.

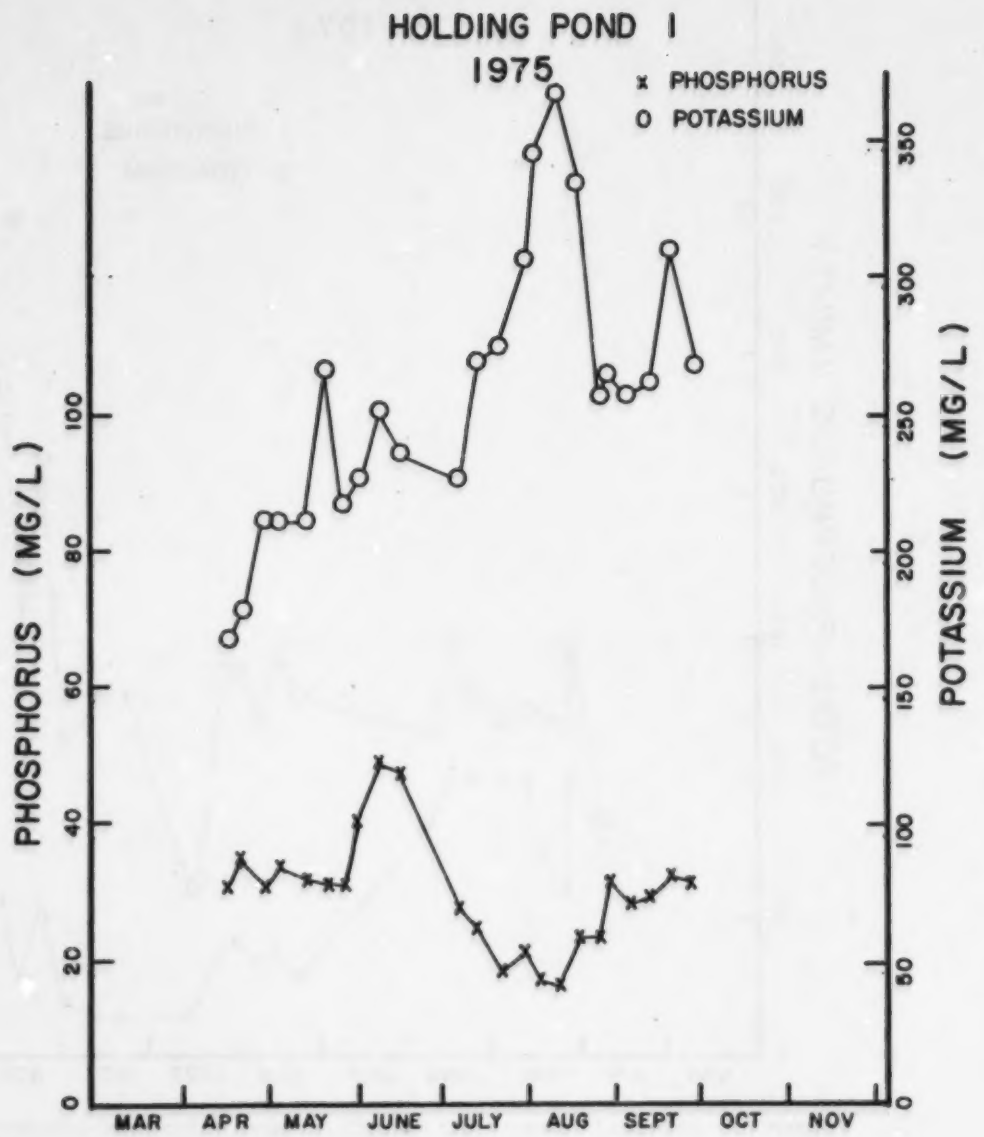

Figure 9. Seasonal changes in phosphorus and potassium concentrations in Holding Pond 1 during 1975.

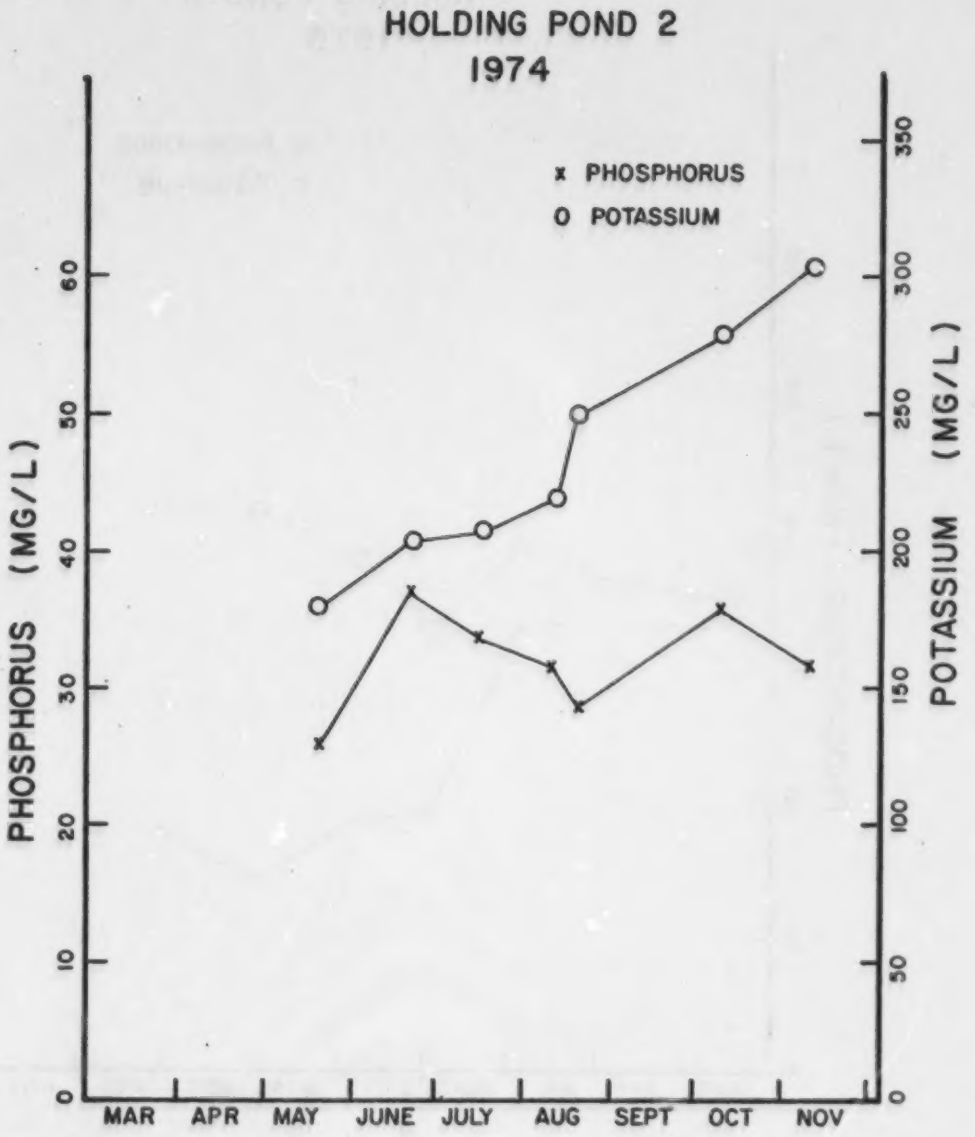

Figure 10. Seasonal changes in phosphorus and potassium concentrations in Holding Pond 2 during 1974.

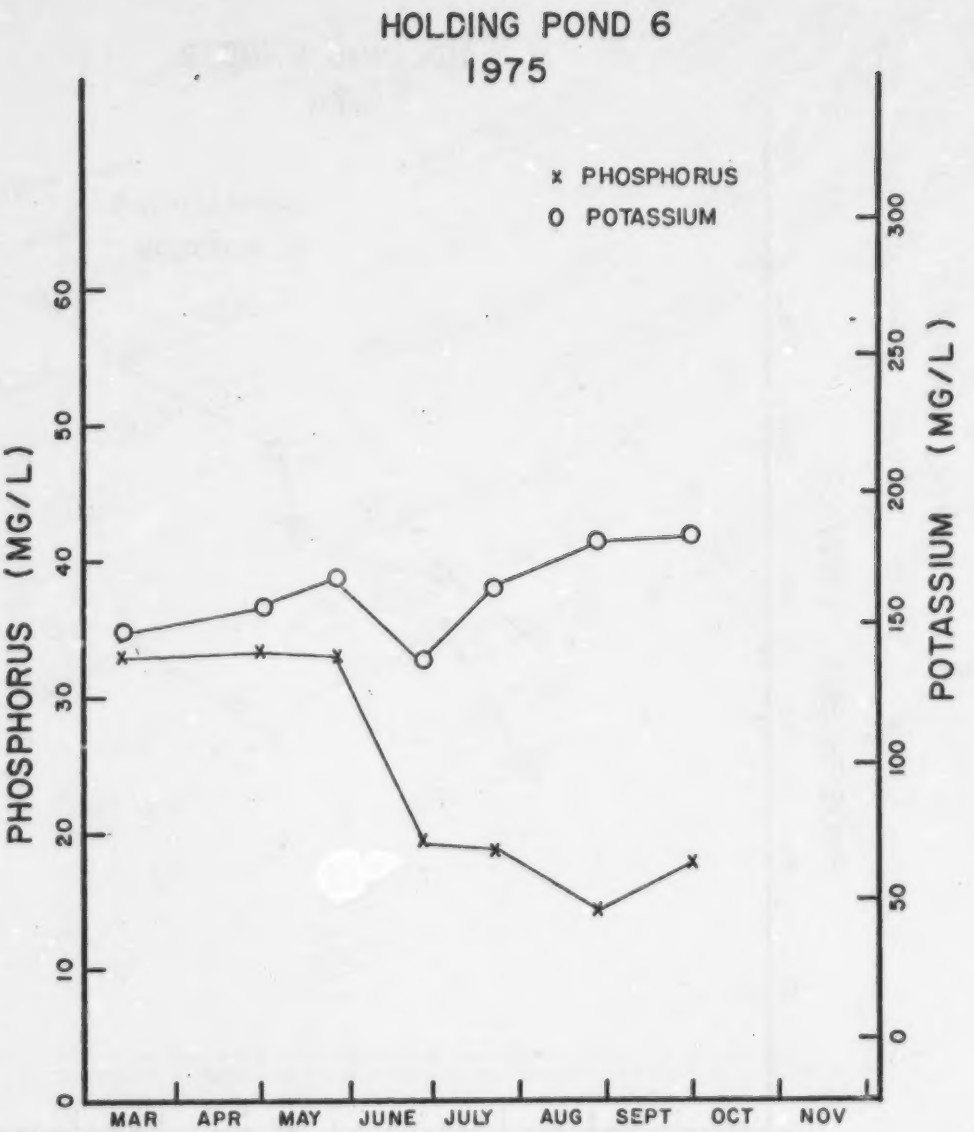

Figure 11. Seasonal changes in phosphorus and potassium concentrations in Holding Pond 6 during 1975.

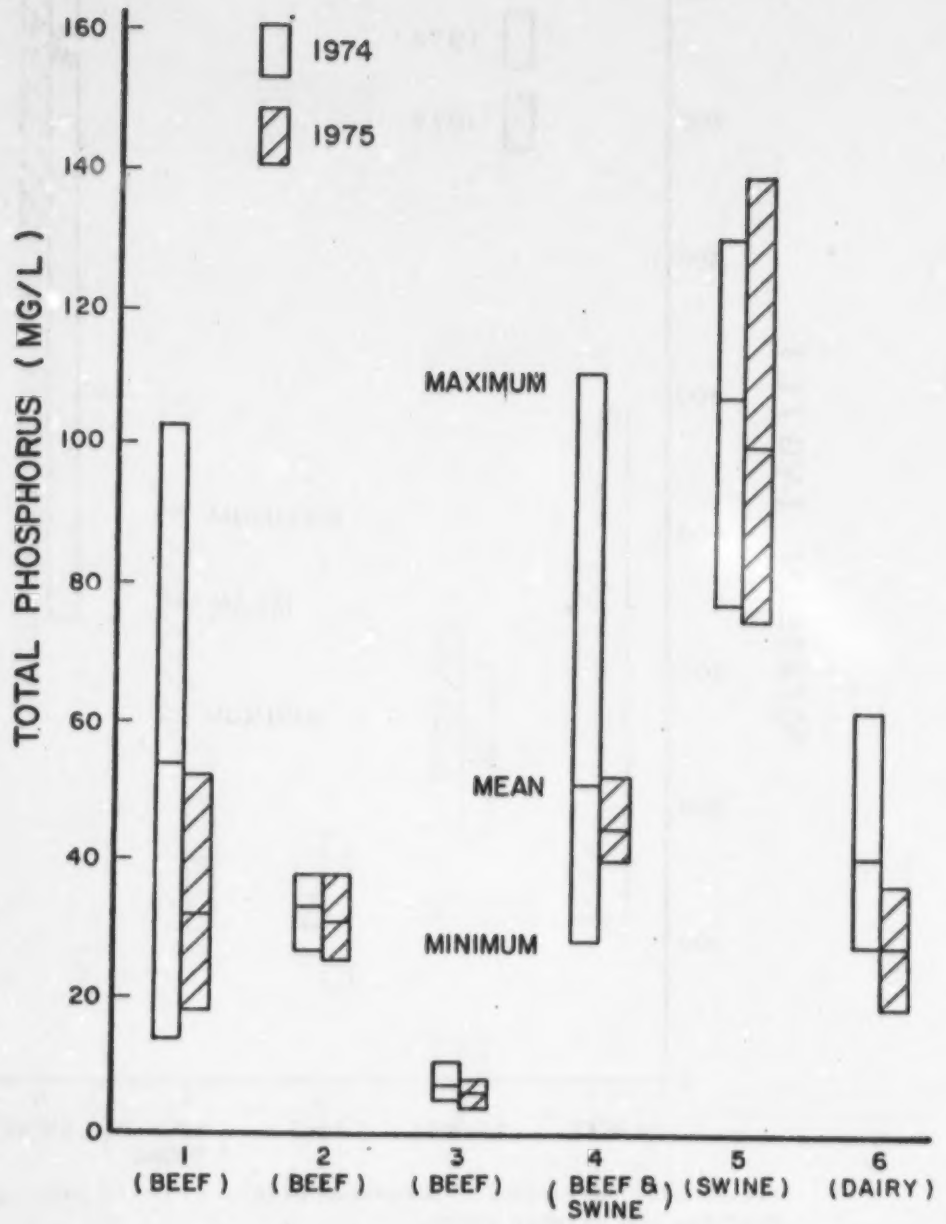

Figure 12. Variation of phosphorus within a runoff holding pond among feedlots and between years.

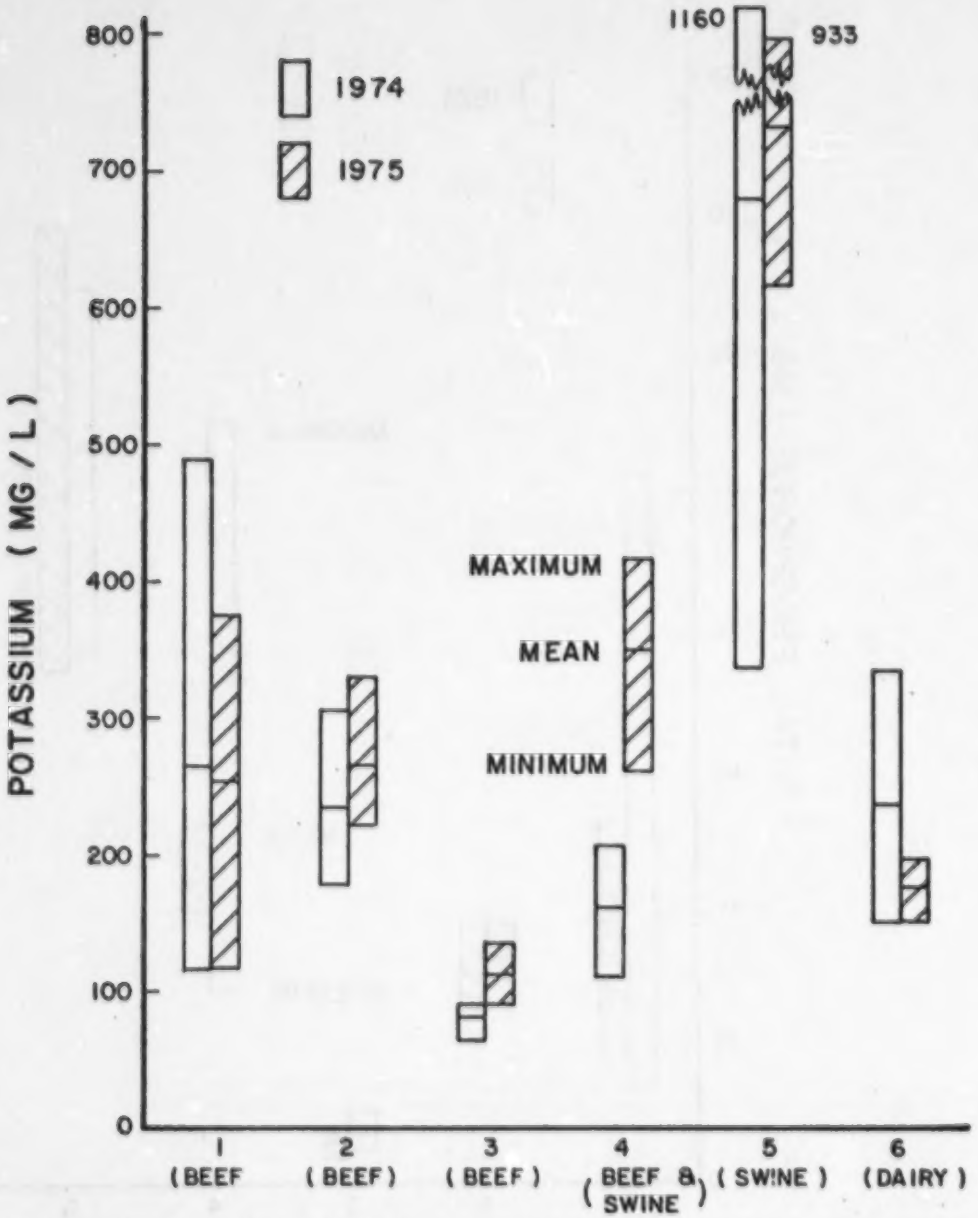

Figure 13. Variation of potassium within a runoff holding pond among feedlots and between years.

swine facilities are mainly due to the basic differences between the animals and between their rations. Causes for differences in both elements among the beef facilities are similar to those for nitrogen differences.

As shown in Figures 12 and 13, phosphorus and potassium concentrations varied greatly between years in the holding ponds studied. These variations are caused by the same factors mentioned for variations in nitrogen concentration--that is, changes in lot management, changes in the animal concentrations, and variations in the annual rainfall patterns. In Feedlot 1 the major change between 1974 and 1975 was the reduced number of animals during 1975. The animal reduction resulted in a sharp decrease in phosphorus concentration and some decrease in potassium concentration. Since Feedlot 3 was not cleaned as often in 1975 as in 1974, potassium and nitrogen concentration increased in 1975. A slight decrease in phosphorus concentration was possibly due to an attraction between the phosphorus and the manure pack which developed on Feedlot 3 in 1975.

Sodium and Chloride

Variations of sodium and chloride concentrations are shown in Figures 14, 15, and 16. The close correlation between sodium and chloride concentrations is attributed to the presence of salt (NaCl) which entered the holding pond via feedlot runoff. Research by Horton et al. (1975) has shown that salt levels in runoff and feedlot manure are directly related to salt levels in the animal feed rations. In general, the sodium and chloride concentration increased throughout the summer months apparently as a result of evaporation. However, the sodium and chloride concentration in Holding Pond 1 decreased in 1974 during the latter portion of the summer and then increased in mid-fall. Reasons for the abnormal sodium and chloride trend observed in Holding Pond 1 during 1974 are not understood. The maximum sodium concentration measured in the holding

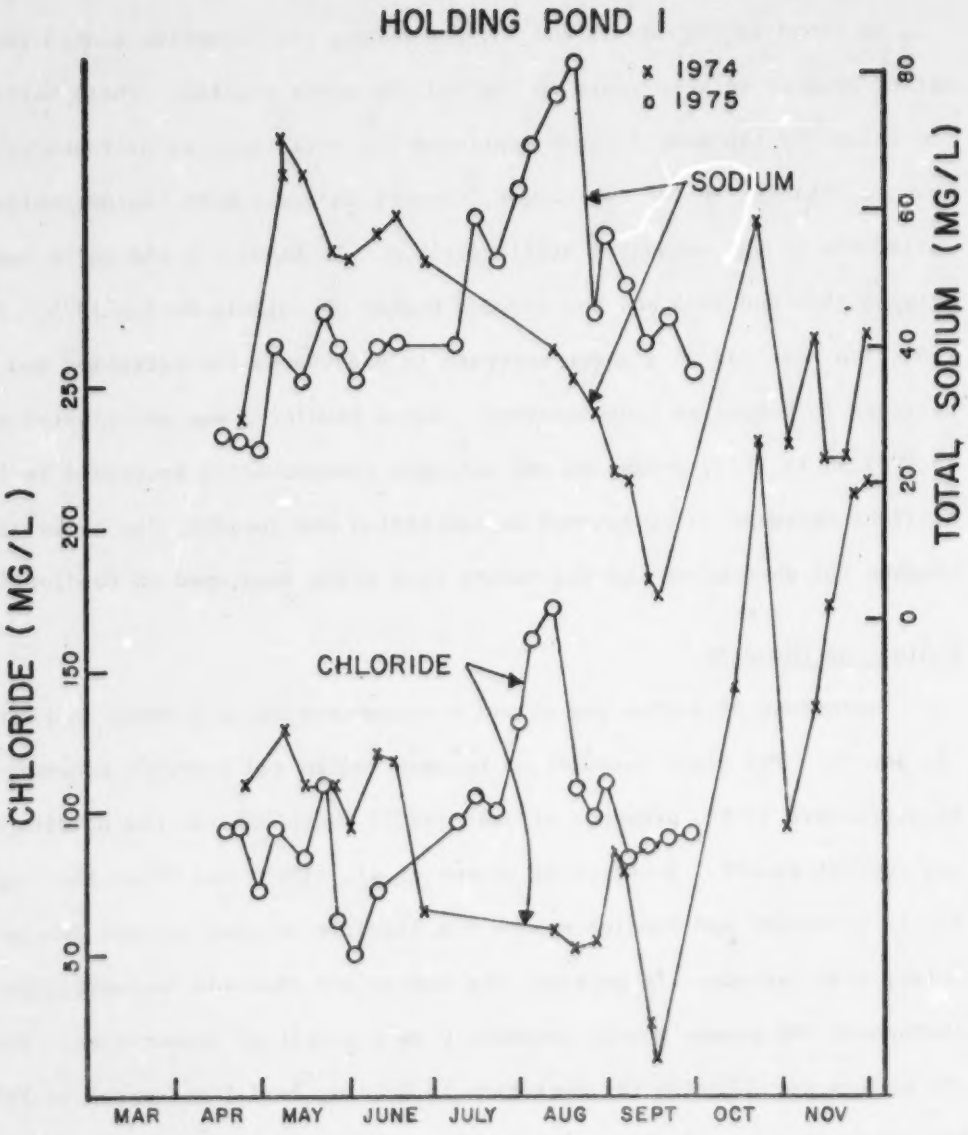

Figure 14. Seasonal changes in sodium and chloride concentrations in holding-pond water.

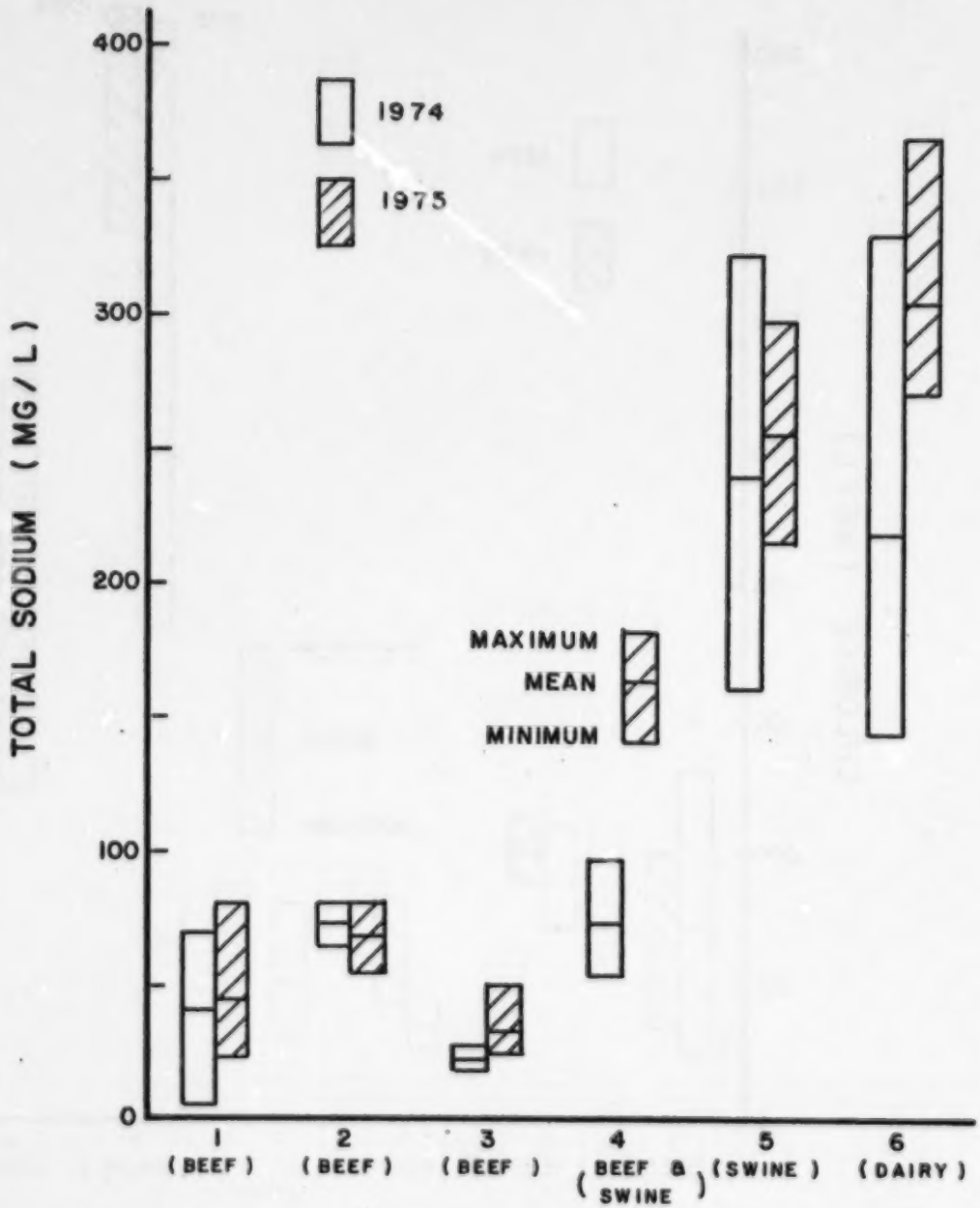

Figure 15. Variation of sodium within a runoff holding pond among feedlots and between years.

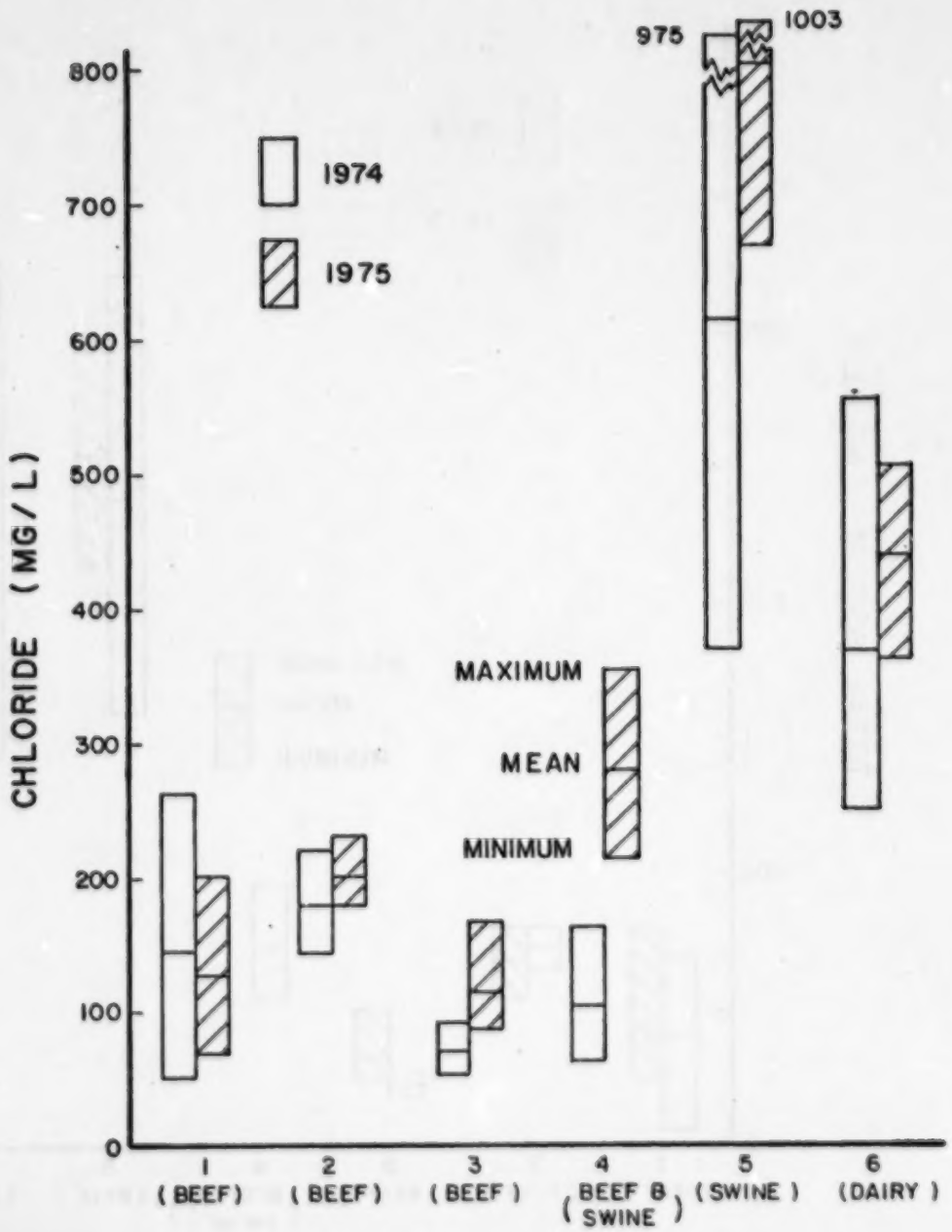

Figure 16. Chloride variations within a runoff holding pond among feedlots and between years.

ponds studied was 365 mg/ℓ which usually is not considered excessive for land application, at least in most humid areas. Assuming a 4-inch application of holding-pond water, the maximum amount of sodium applied per acre would be 330 pounds. In Texas, Mathers and Stewart (1971) found that grain sorghum yields were not depressed using sodium application rates approaching 600 pounds per acre. Braids (1972) points out that higher rainfall areas would allow even larger application rates.

Total Solids

The seasonal changes in the solids concentration in Holding Pond 1 are shown in Figure 17. These changes in the solids concentration closely resemble the seasonal variations of nitrogen and phosphorus concentration. The decline in the solids concentration during the summer months is primarily the result of decomposition and settling. With the warm summer temperatures, increased microbial activity raises the decomposition rate of solids in the holding pond. Also during the summer, a decrease in the number of rainfall-runoff events reduces mixing and circulation of the holding-pond water, allowing for a greater degree of solids settling. Figure 18 portrays differences in the solids concentration among systems as well as year-to-year changes in each system.

The percent of the total solids which were suspended is listed in Table 3. The suspended portion of the total solids remained relatively constant throughout the season as well as year-to-year on each system. Since the measured solids concentration consists of only suspended and dissolved, the dissolved portion of the total solids would also be constant.

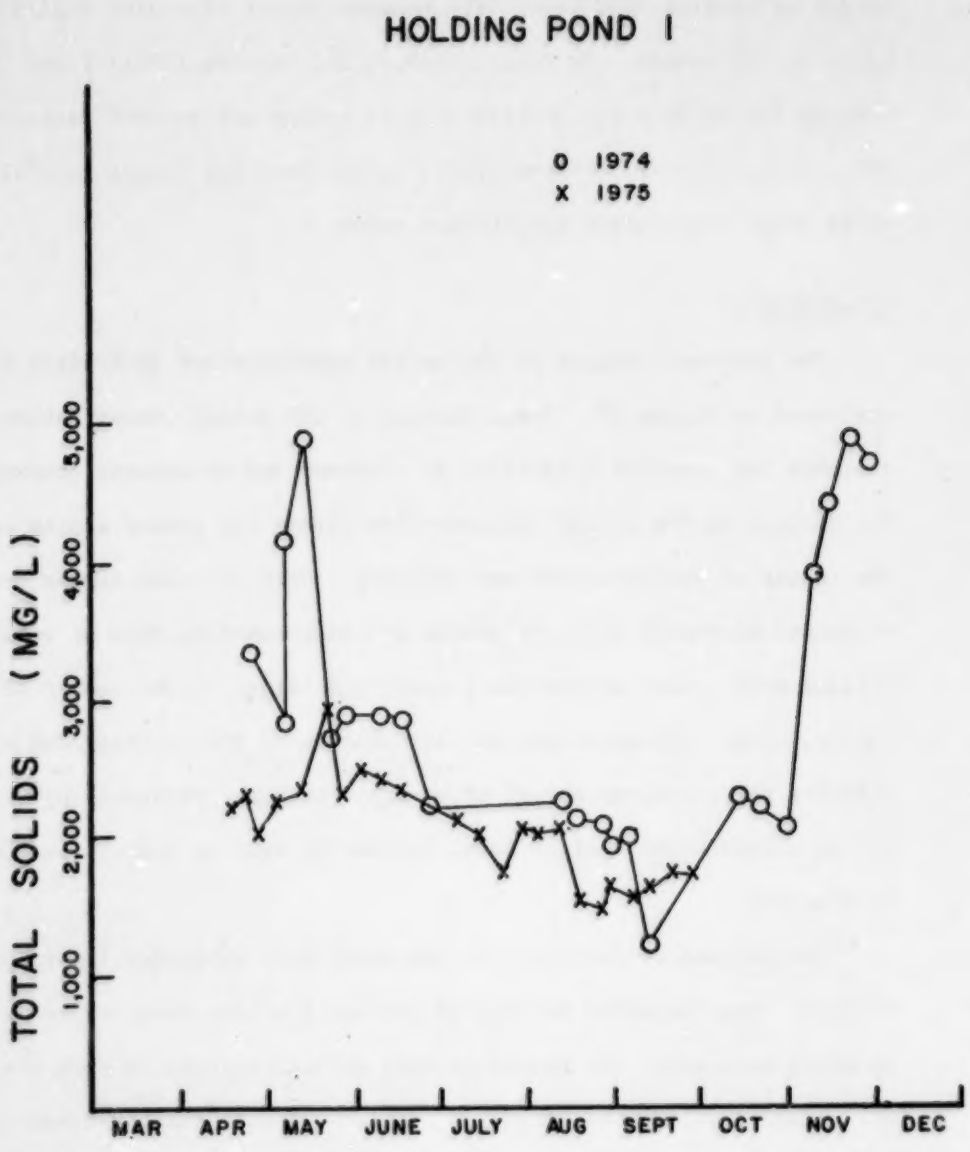

Figure 17. Seasonal variation in the total solids concentration in holding-pond water.

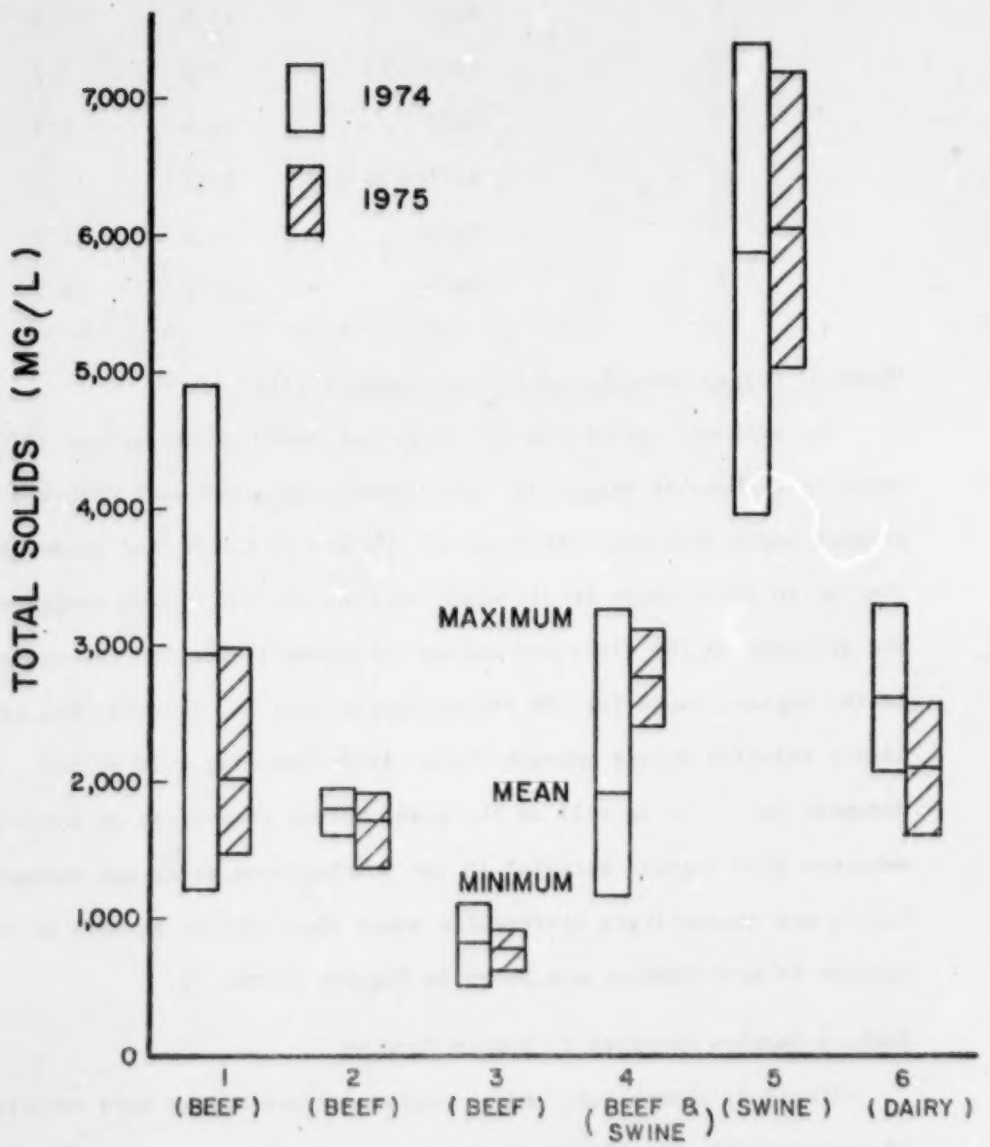

Figure 18. Variation of total solids within a runoff holding pond among feedlots and between years.

Table 3. Average Percent of Total Solids in Holding-Pond Water That Are Suspended

Farm	Operation	Average Percent 1974	1975
1	Beef	13.0	11.9
2	Beef	8.8	8.8
3	Beef	10.6	8.5
4	Beef & Swine	14.7	15.3
5	Swine	24.0	21.4
6	Dairy	11.8	15.5

Chemical Oxygen Demand (C.O.D.) and Conductivity

The seasonal variations of C.O.D. and conductivity during 1974 in Holding Pond 1 are shown in Figure 19. The trends exhibited were observed in all the holding ponds studied. The seasonal changes in C.O.D. and conductivity were similar to the changes in nitrogen, phosphorus, and solids concentrations. The decrease in the dissolved solids concentration during the summer months is the primary cause for the corresponding drop in conductivity, since a direct relation exists between conductivity and dissolved solids. The summer decrease in C.O.D. as well as the lower solids concentration gave additional evidence that organic material in the holding-pond water was decomposing. C.O.D. and conductivity differences among the systems, as well as year-to-year changes in each system, are shown in Figures 20 and 21.

Surface Samples Compared to Bottom Samples

Nitrogen, phosphorus, and potassium concentrations were compared to determine if statistically significant differences existed between holding-pond water samples collected near the surface and near the bottom of the holding ponds.

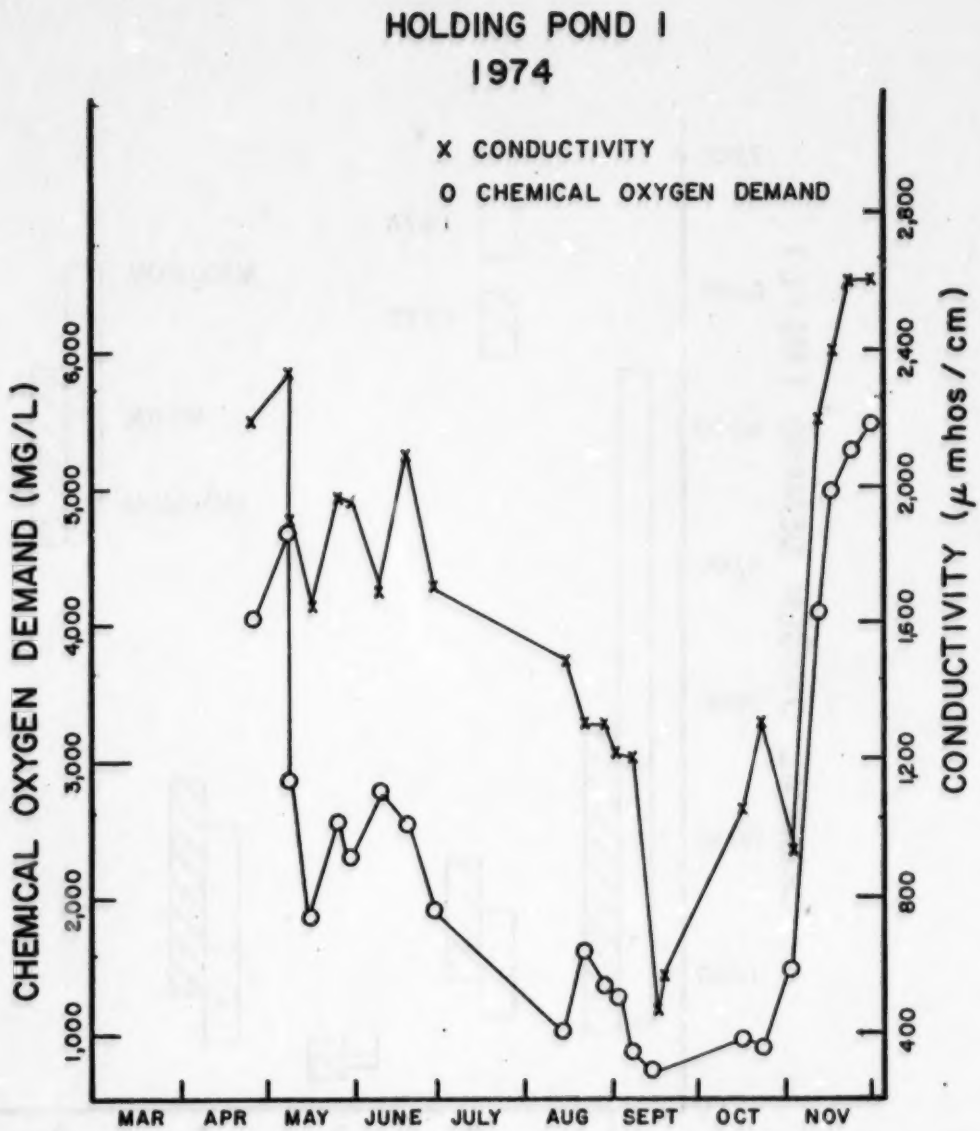

Figure 19. Seasonal changes in the conductivity and chemical oxygen demand of holding-pond water.

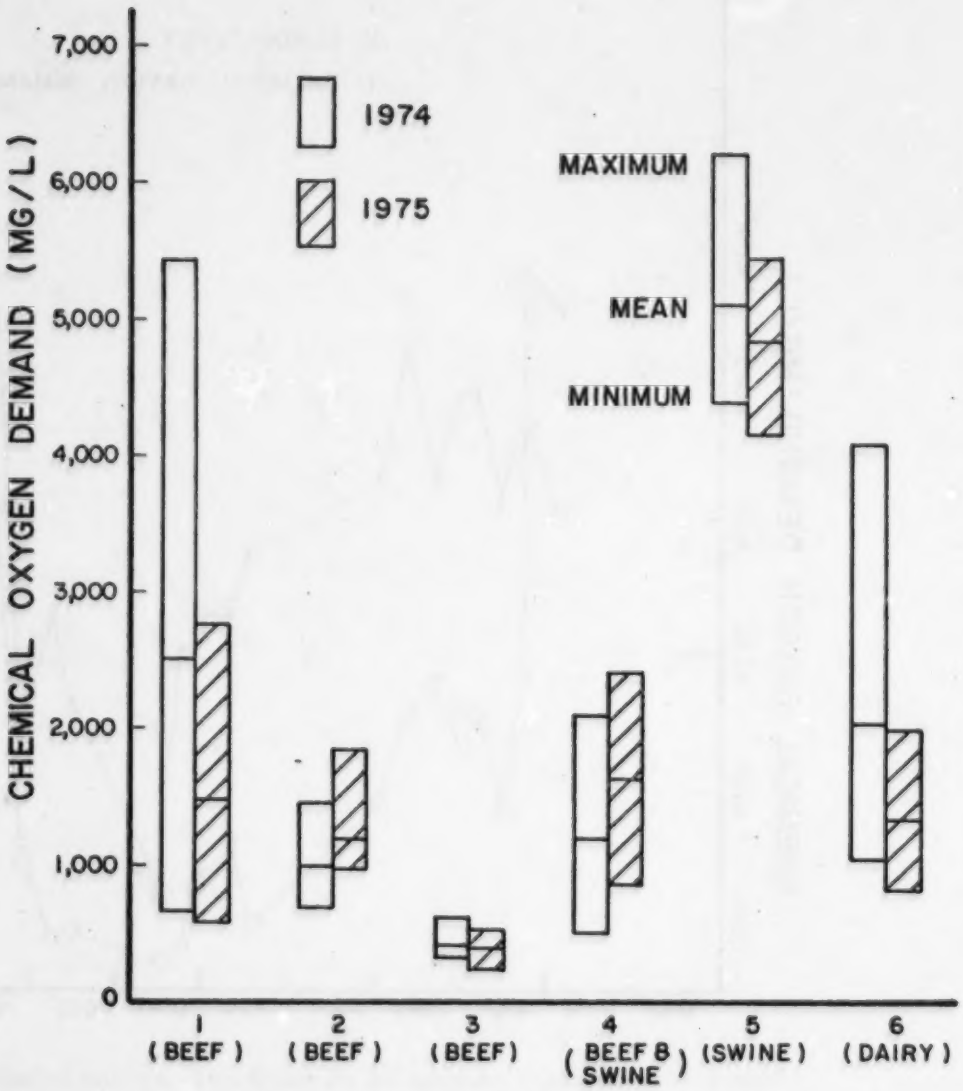

Figure 20. Chemical oxygen demand changes within a runoff holding pond among feedlots and between years.

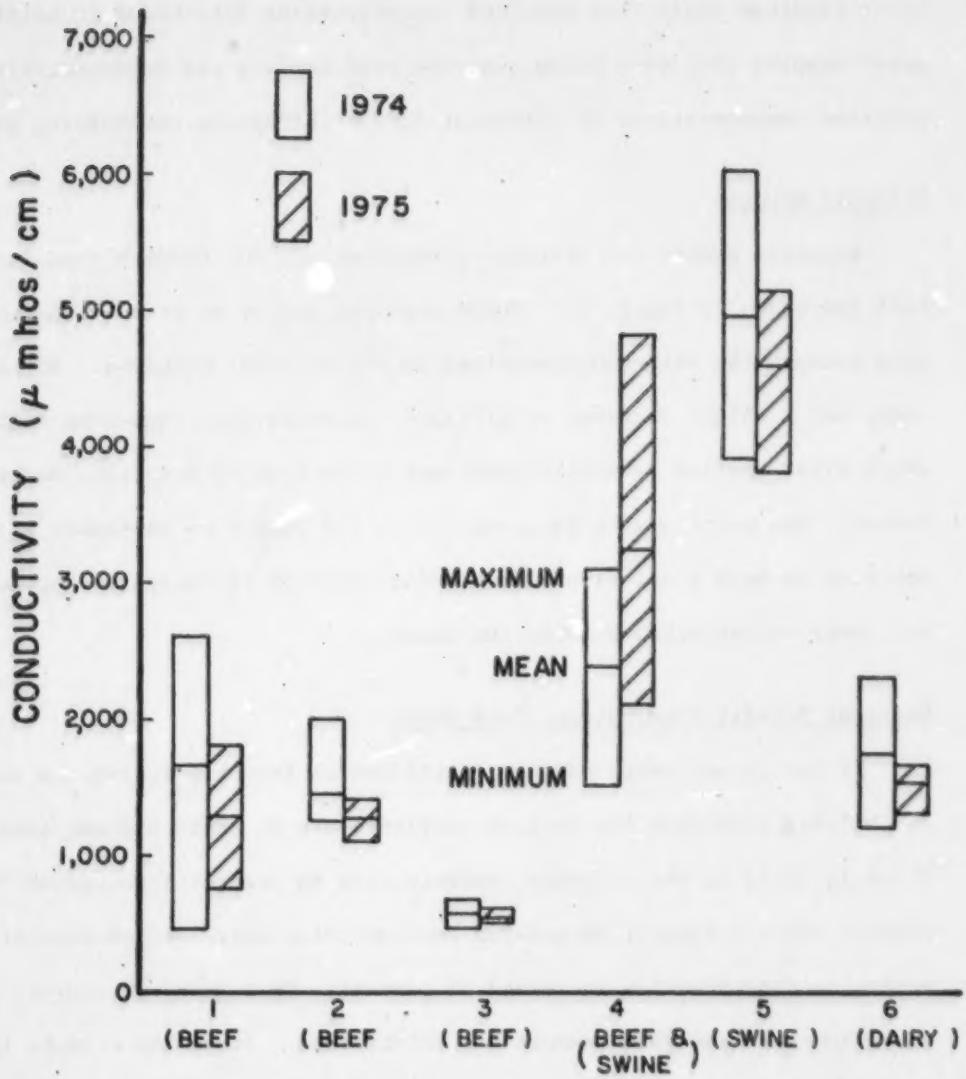

Figure 21. Conductivity variations within a runoff holding pond among feedlots and between years.

At the 5-percent level, no significant difference between nitrogen, phosphorus, or potassium concentrations was detected when comparing surface samples to bottom samples. There was a trend for slightly higher ammonia nitrogen concentrations near the bottom, although not significant at the 5-percent level. These findings imply that nutrient concentrations determined in holding-pond water samples that were taken near the pond surface are representative of nutrient concentrations at different depths throughout the holding pond.

Rainfall Effects

Rainfall events and nitrogen concentrations for Holding Pond 1 during 1974 are shown in Figure 22. There does not appear to be a strong relationship between the nitrogen concentration and rainfall received. For example, there was a slight increase in nitrogen concentration after some rainfalls, while after similar rainfalls, nitrogen concentration sometimes decreased. However, one particularly large rainfall, 4.8 inches on September 12, 1974, appeared to have a dilution effect, since each of the measured constituents had lower concentrations after the event.

Nutrient Benefit From Holding-Pond Water

If the farmer wants maximum fertilization from his system, he must dewater the holding pond when the desired nutrients are at their highest levels. As shown in Table 4, the nitrogen concentration in Feedlot 1 decreased 38 percent between May and August; phosphorus concentration decreased 48 percent, but potassium concentration increased 58 percent. By August, of course, some water has evaporated and some ammonia has volatilized. Since the figures in Table 4 are based on concentrations and not on the total nutrients present in the pond, the actual quantities of nitrogen and phosphorus lost would be greater, and the amount of potassium gained would be less than the figures suggest.

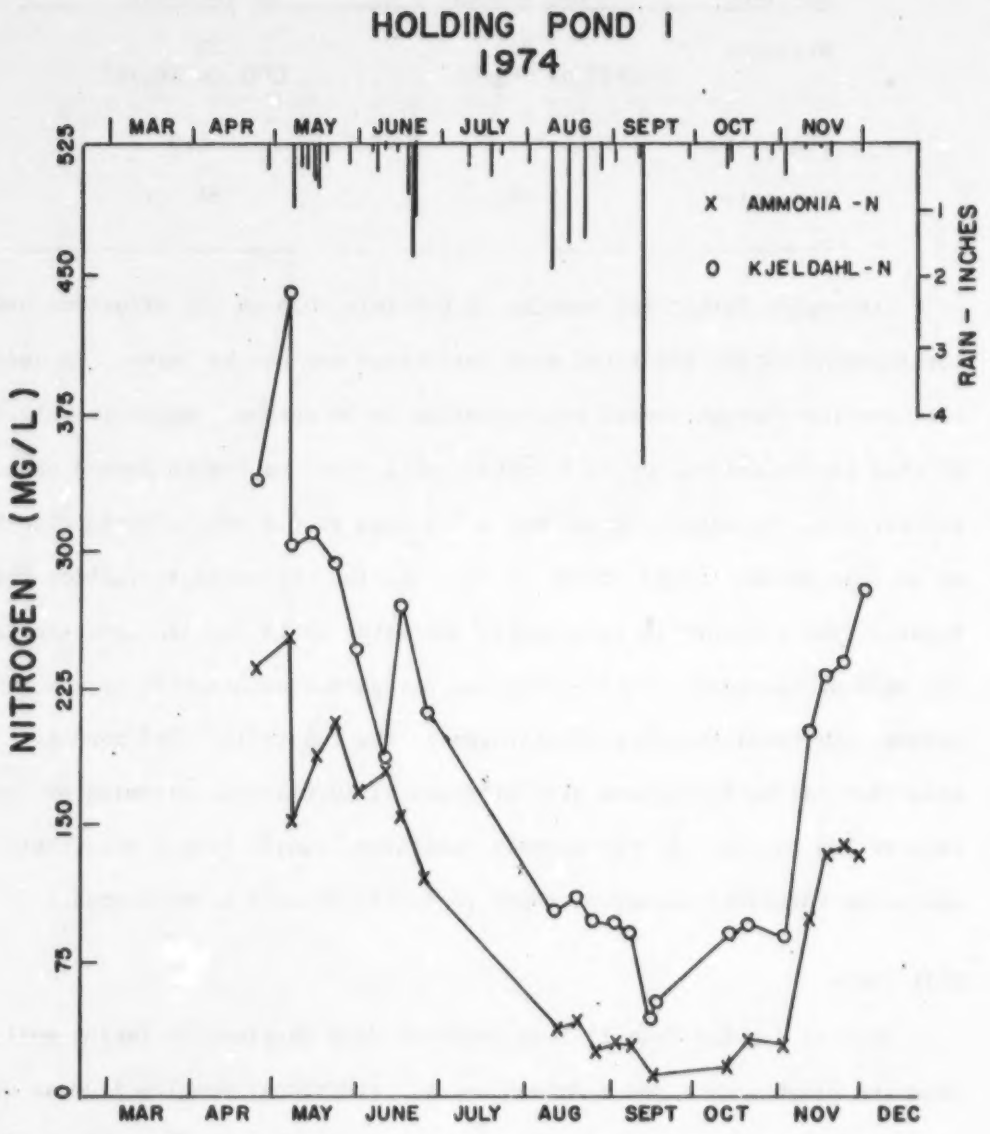

Figure 22. Daily rainfall and changes in nitrogen concentrations during 1974 in Holding Pond 1.

Table 4. Nutrient Content of Applied Holding-Pond Water

Nutrient	May 14, 1975 Lb./ac.-in.	August 12, 1975 Lb./ac.-in.
Nitrogen	34 (62% as NH_3-N)	21 (20% as NH_3-N)
Phosphorus	7.7	4.0
Potassium	49	84

Although a fertilizer benefit is possible through the effective use of holding-pond water, the total area fertiliz d may not be large. In central Illinois the average annual precipitation is 36 inches. Approximately 65 percent of this precipitation, or 23.4 inches, will occur as runoff from a paved feedlot surface. Feedlot 1, which has a lot area of 0.8 acres, would then have an average annual runoff volume of 18.7 ac.-in. Assuming irrigation from Holding Pond 1 occurs in late April, the water would contain approximately 300 mg/ℓ of nitrogen. Multiplying the nitrogen concentration by the runoff volume, the total quantity of nitrogen in the runoff is 1,270 pounds. The area that can be fertilized with nitrogen is 10.6 acres, assuming an application rate of 120 lb./ac. As the example indicates, runoff from a relatively large operation furnishes enough nitrogen to fertilize only a small area.

SOIL TESTS

Several samples from 15-foot profiles were obtained by taking soil from the flights of a power-driven auger. Additional samples from as much as 2 feet deep were obtained with manual tube samplers. The soil samples were analyzed by the Agronomy Department Soil Testing Laboratory, University of Illinois at Urbana-Champaign, using both published and unpublished methods.

A number of soil tests were made on the cropland at System 1 (Figure 23) to determine if differences existed between feedlot-waste disposal areas and commercially fertilized areas. Twenty acres of cropland used for disposal of the holding-pond water received a total application of approximately 4 inches of holding-pond water during the spring and summer of 1974. This same area received no solid manure in 1974, but had received both holding-pond water and approximately 10 tons of solid manure per acre in 1973. Appropriate solids analyses are given in Table 5. A second area used mainly for the disposal of solid manure had an application rate of approximately 10 tons/ac. in 1974 and two 10 ton/ac. applications in 1973. Using the data in Table 5, approximately 280 pounds of nitrogen, 70 pounds of phosphorus, and 250 pounds of potassium was applied with each 10 ton/acre application. In 1974 this area also received an additional 120 lb./ac. of nitrogen applied as anhydrous ammonia. The commercially fertilized area received an application of 120 lb./ac. nitrogen, 46 lb./ac. phosphorus, and 90 lb./ac. potassium in 1974. A similar fertilizer application rate was used in 1973.

Soil profiles in the three areas were sampled to a depth of 15 feet in August, 1974. As shown in Figures 24, 26, 27, and 28, no appreciable differences were found among the areas when comparing Kjeldahl nitrogen, phosphorus or potassium.

The nitrate nitrogen concentration (Figure 25) was different among the three areas. The commercially fertilized area exhibited a concentration peak at the 1-foot depth, which was about three times greater than the nitrate concentration measured in the other areas at the same depth. This peak is thought to be commercial fertilizer nitrogen which had not been used by the growing corn plant. The cropland area where runoff was applied exhibited a relatively high nitrate nitrogen concentration at the soil surface. This

Table 5. Manure Solids, Settling Basin Solids, and Holding-Pond Sediment Analyses

	Manure Solids	Settling Basin Solids	Holding-Pond Sediment
Total Kjeldahl nitrogen	28,100*	19,060	20,130
Total phosphorus (1)	6,250*	3,940	6,660
Total potassium (1)	27,200*	10,500	12,300
Total sodium (1)	1,380	783	933
Percent moisture (2)	51.2	79.3	84.6
No. of samples	8	11	6

(1) ppm air dry basis
(2) percent wet weight basis

*These concentrations appear high when compared to values given in some literature, but we have no reason to doubt the analyses.

peak was attributed to the recent oxidation of nitrogen forms applied to the area by irrigation of holding-pond water. The same area also had a relatively high nitrate concentration occurring from the 3-foot to 9-foot depth which peaked near the 7-foot level. At this time there is no apparent explanation for this high concentration. The cropland which received mainly solid manure had no significant nitrate nitrogen buildup throughout the profile sampled.

The greatest degree of difference among the areas samples was in the measured sodium concentration (Figure 29). Although there was a slight increase in the sodium concentration with depth, the commercially fertilized area did not have a sodium buildup in the profile sampled. The disposal area which received mainly holding-pond water had roughly twice the concentration in the upper 10 feet of soil as did the commercially fertilized area. However, the disposal area which received mainly solids had much higher sodium concentrations in the upper 8 feet of soil, from four to six times greater than the concentration observed in the commercially fertilized area. Our calculations

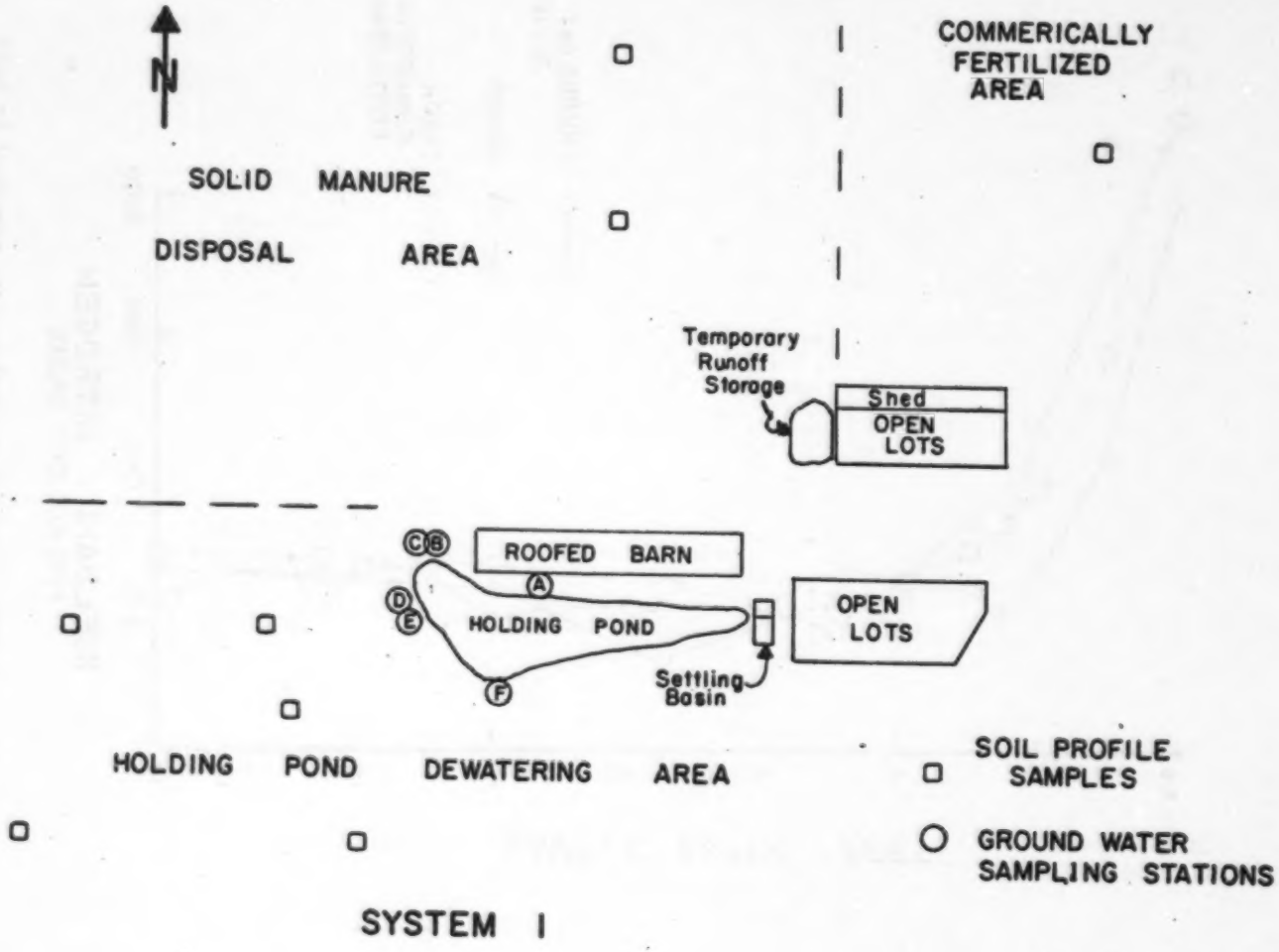

Figure 23. Locations of soil auger holes and ground water sampling stations.

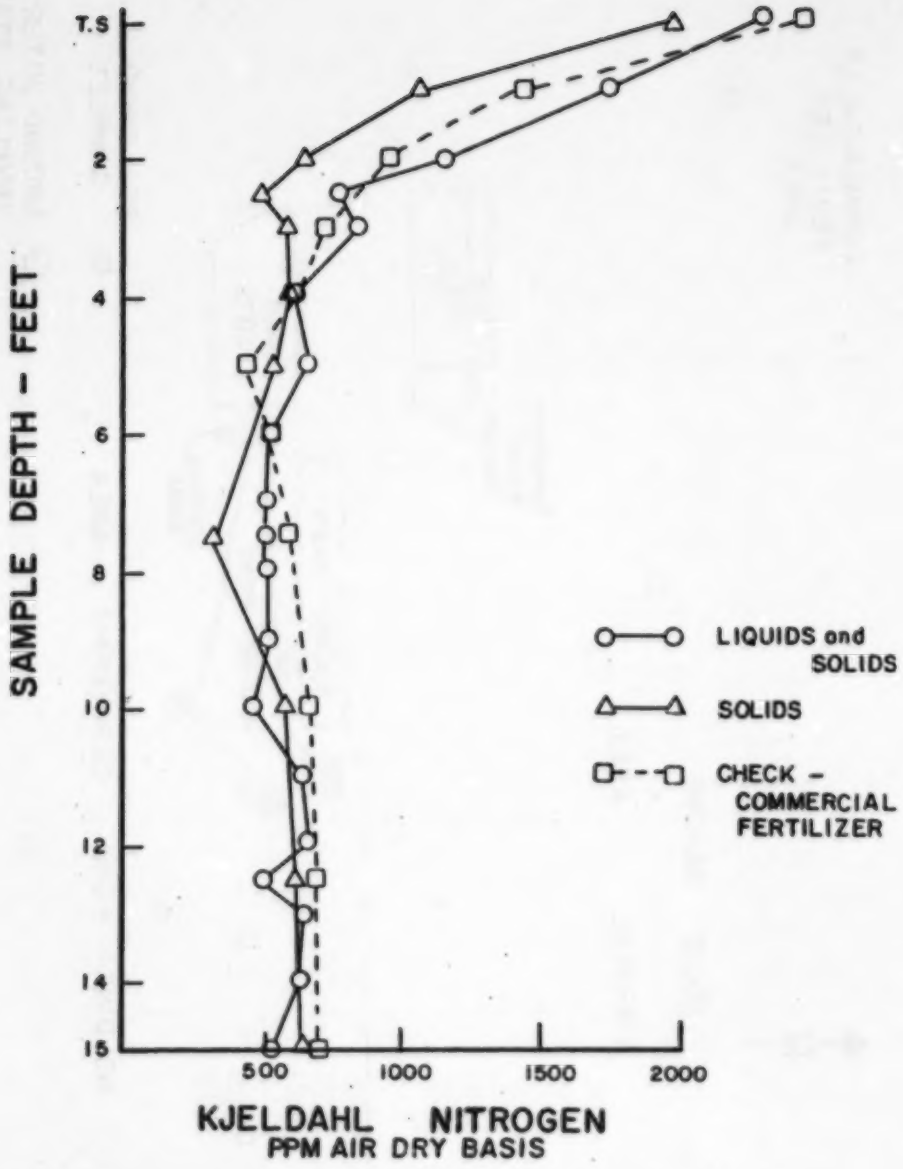

Figure 24. Kjeldahl nitrogen concentrations measured in soil samples from cropped land at System 1.

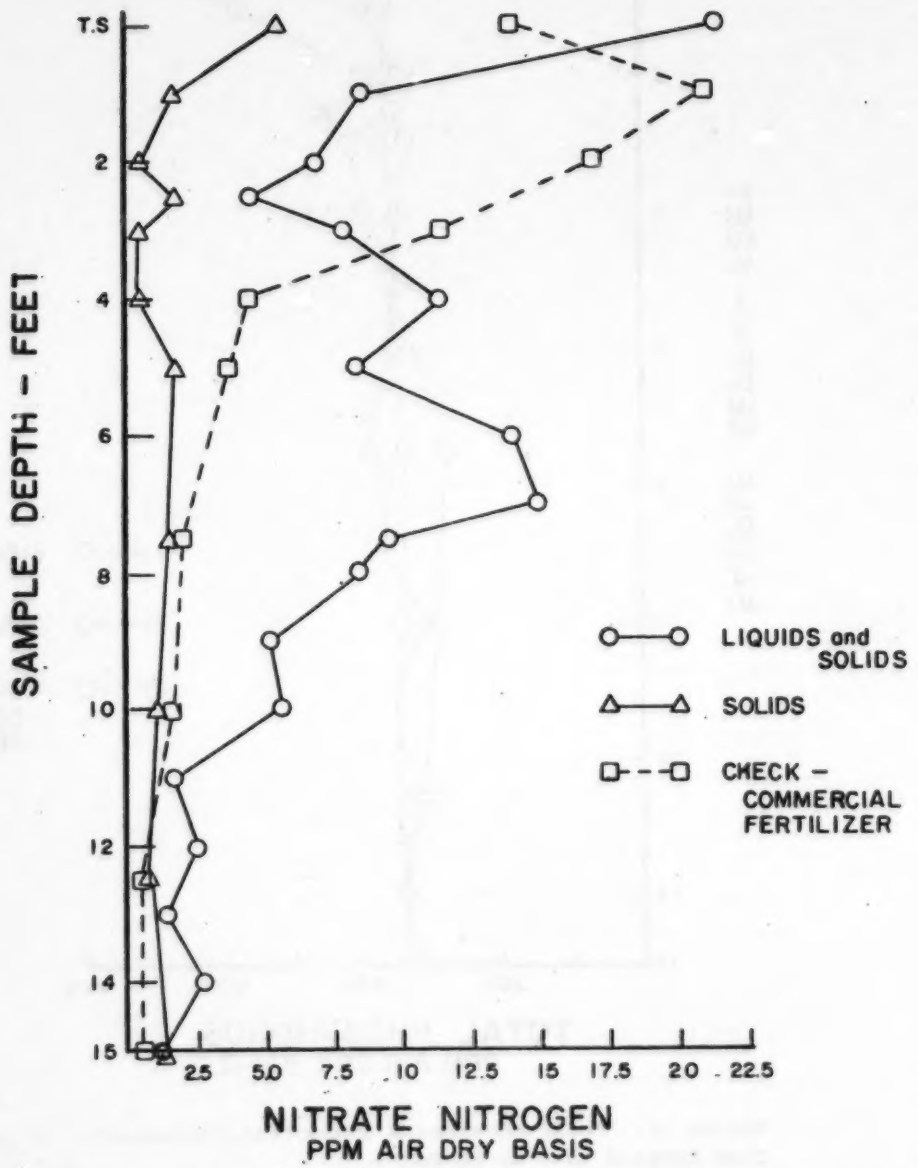

Figure 25. Nitrate nitrogen concentrations measured in soil samples from cropped land at System 1.

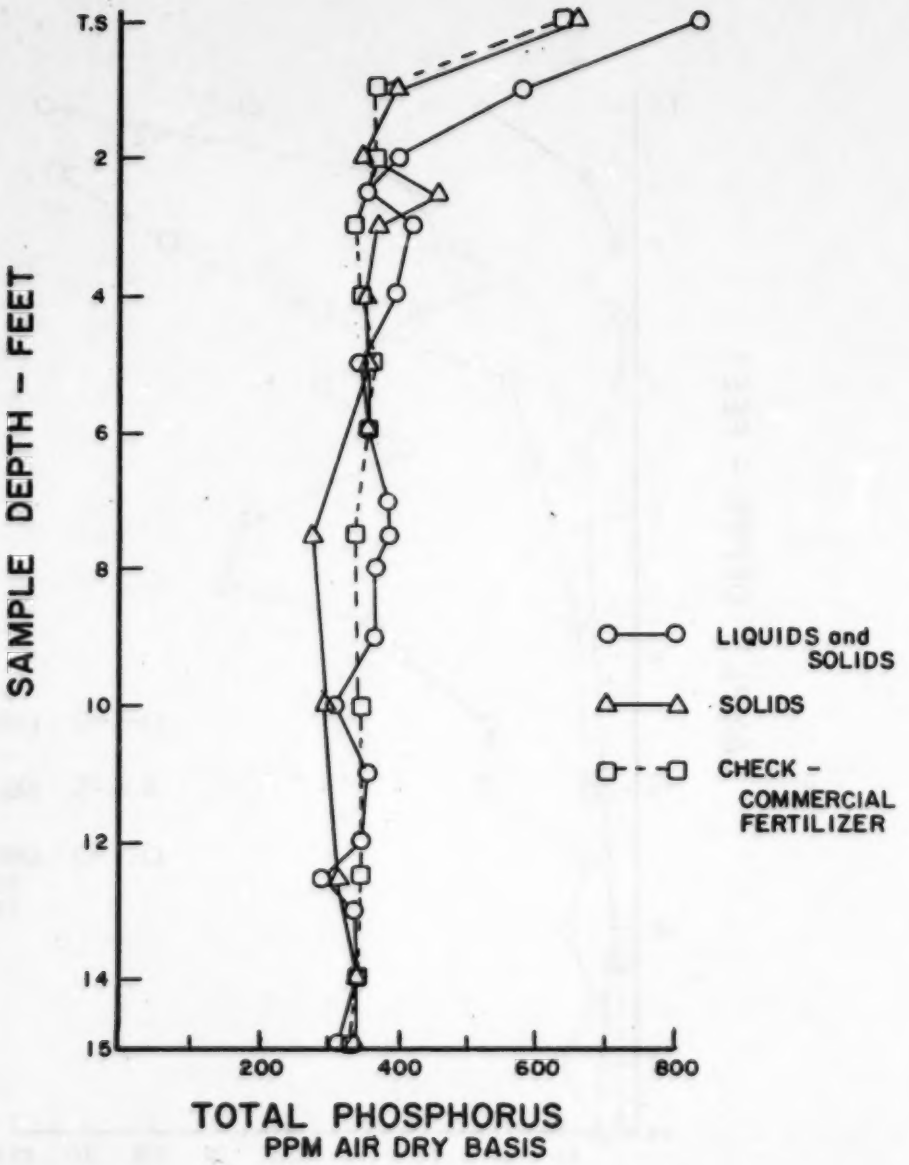

Figure 26. Total phosphorus concentrations measured in soil samples from cropped land at System 1.

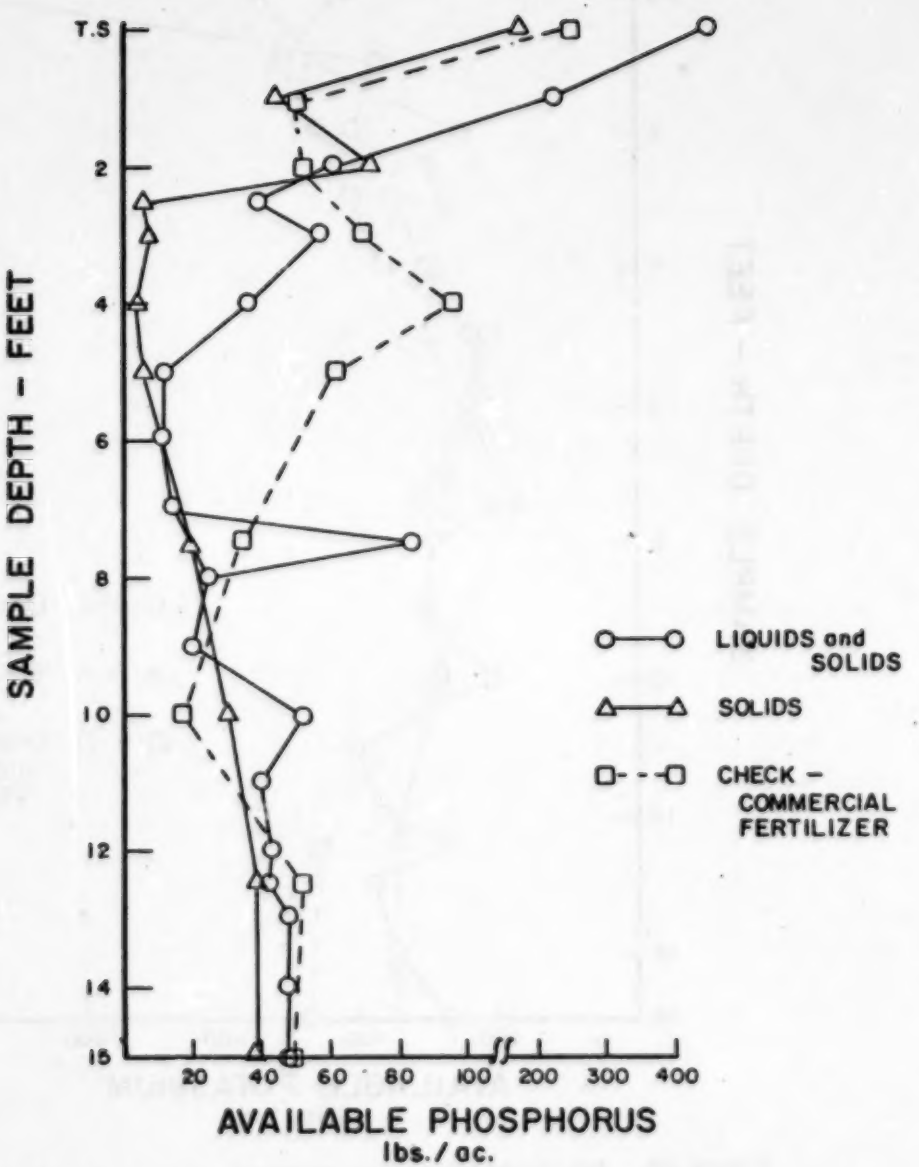

Figure 27. Available phosphorus measured in soil samples from cropped land at System 1.

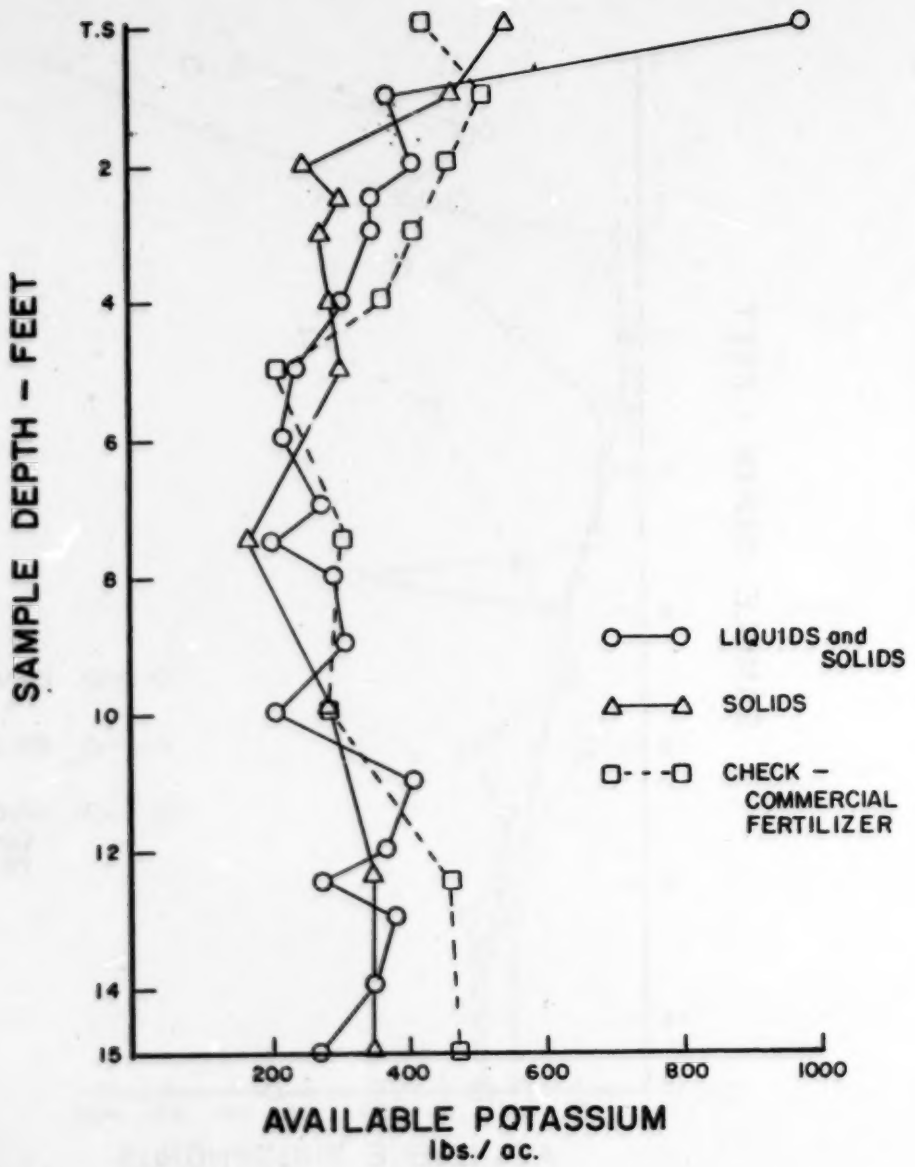

Figure 28. Available potassium measured in soil samples from cropped land at System 1.

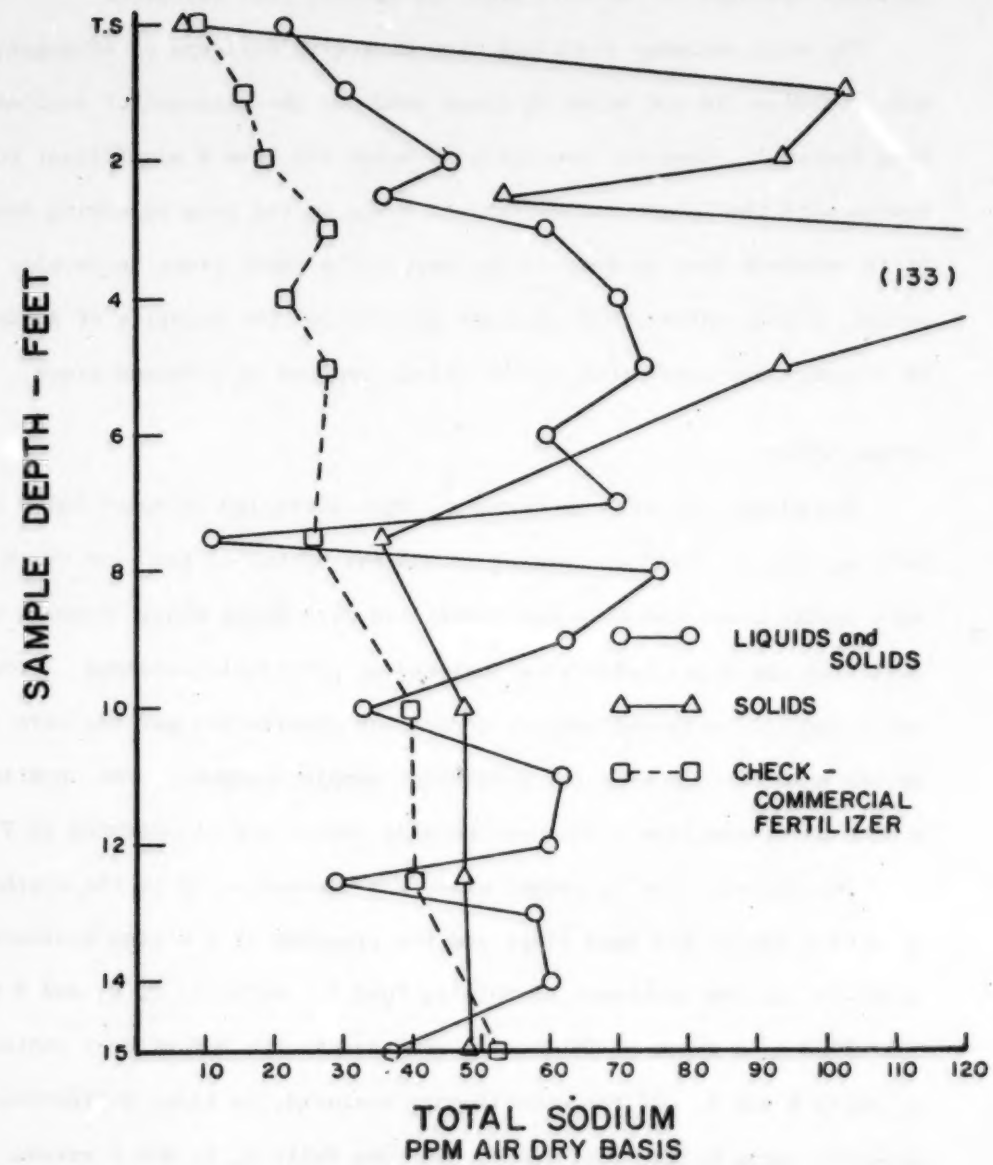

Figure 29. Total sodium concentrations measured in soil samples from cropped land at System 1.

and previous research by Gilbertson et al. (1975) has shown that a major portion of the sodium is removed from the feedlot area in the manure solids, while a relatively small portion goes into the holding-pond water. The sodium concentrations measured in the soil profiles support that research.

The soil analyses indicated that excessive buildups of nitrogen, phosphorus, and potassium did not occur in areas used for the disposal of feedlot wastes from System 1. However, the disposal areas did have a significant buildup of sodium with the larger concentrations being in the area receiving manure solids. It is possible that in some soils, especially those prone to develop "slick spots", sodium rather than nitrogen may control the quantity of manure solids or holding-pond water that can be safely applied to cropland areas.

GROUND WATER

PVC pipes, 3/4 inch in diameter, were installed in auger holes near Holding Pond 1. Sand was packed around the bottom of the pipe which had been slotted, and the hole was backfilled with tight clay. Samples of soil from the auger holes were analyzed as previously outlined. Ground-water samples, obtained monthly during the observation period, were analyzed by the same methods used for pond-water sample analyses. The locations of ground-water sampling wells near Holding Pond 1 are illustrated in Figure 23.

The general flow of ground water was assumed to be in the northwest direction due to the land slope and the presence of a stream approximately 3,000 ft. to the northwest of Holding Pond 1. Wells A, C, E, and F were installed to a depth of 20 feet as compared to the 8-foot deep installation of Wells B and D. Of the constituents measured, no large differences were detected among Wells C, E, and F. Because Wells C, E, and F extend into the continually saturated zone and since little difference existed among these

wells, it was thought that Wells C, E, and F represented typical ground-water quality in the immediate area. In addition, the tight clay bottom of Holding Pond 1 severely limited the vertical seepage of holding-pond water.

As listed in Table 6, Well A had appreciably larger constituent concentrations than did Wells C, E, and F. Well A was located such that holding-pond water covered the ground surface during higher stage periods and liquid manure from the nearby barn drained across the same area during low holding-pond stages. Soil samples from the auger hole at Well A verified the presence of considerably larger amounts of nutrients than were present in the other auger holes.

Wells B and D had larger concentrations of the chemicals than had the background levels of Wells B, E, and F; and Wells B and D had larger concentrations of nitrate and chloride than had Well A. Since Wells B and D were at a shallow depth and located near the holding pond's earth embankment, constituent levels above the background level were attributed to lateral seepage from the holding pond. Since nitrate and chloride are considered mobile ions, their presence in relatively large concentrations in the shallow wells supports the idea that there was some lateral seepage of water. Research by Chang et al. (1974) indicates that holding ponds naturally seal very well, but this may not be true for bank areas which are subject to alternate wetting and drying conditions.

GENERAL MANAGEMENT ASPECTS

In general, the cooperating farmers reported no serious problems in management of the systems. Solids in the settling basins could normally be satisfactorily removed with a conventional tractor and loader, then hauled and spread onto cropland. Cleaning frequency averaged once every one or two months.

Table 6. Ground Water Quality Near Holding Pond 1 (Average of 6 sampling dates)

	Deep Wells (20 ft.)		Shallow Wells (8 ft.)
	Well A	Wells C,E,F	Wells B,D
Nitrate nitrogen - mg/ℓ	4.67	1.93	8.2
Ammonia nitrogen - mg/ℓ	0.55	0.20	0.51
Total potassium - mg/ℓ	22.2	5.9	13.0
Total sodium - mg/ℓ	46.9	26.2	15.3
Chloride - mg/ℓ	33.2	5.9	41.7
Conductivity - μmhos/cm	840	478	571

Clogging of the settling basin outlet riser was initially a problem in Systems 3 and 5. Pump and screen clogging was also a problem with System 6. In 1974, Ron Lawfer (System 3) installed an additional outlet screen constructed of a wood frame and 9-gauge expanded metal with 3/4 inch by 1½ inch diamond-shaped openings. This screen was placed along the sidewall of the basin for nearly the full length, with a small distance left between the screen and sidewall. Liquid could then pass through the screen at any point along the length and flow between the screen and sidewall to the outlet pipe. This device proved effective in solving the clogging problem. The design was later slightly modified and the device installed on Systems 5 and 6, again with successful results. This screen, which is illustrated in Figure 30, has the potential for greatly reducing or eliminating outlet clogging problems when they occur.

Holding-pond dewatering was accomplished with a wide variety of pumping and distribution equipment, ranging from small, electric, submersible pumps and perforated plastic tubing, to high-capacity, tractor-PTO-driven irrigation pumps connected to portable aluminum irrigation pipe and large gun-type sprinklers.

Dewatering was accomplished from early spring to late fall, often with the liquid applied to growing crops with no apparent detrimental effects. The farmers did not feel that dewatering posed any particular problem and most seemed to accomplish it in a timely fashion even though it was a relatively low priority task in the normal farming operation.

Capacities of the holding ponds and settling basins were adequate for the conditions encountered during the study period. Illinois Soil Conservation Service design standards were used in every system. For holding ponds, standards specify a minimum of 12 inches of runoff storage for earth feedlot areas and 15 inches for paved areas. For settling basins, the standard is a minimum of 2,000 cubic feet of capacity per acre of feedlot. At no time during the study period did any holding pond overflow or even threaten, indicating that the capacity and dewatering schedule were adequate. There were no exceptionally large runoff events during the study period.

Odor was not considered a problem from any of the settling basins, holding ponds, or during disposal operations. Brief periods of odor emissions occurred from the holding ponds, primarily in the early spring as the pond warmed up and biological decomposition of the winter-stored wastes began.

USE OF SITES FOR DEMONSTRATION

As noted earlier, the Lawfer runoff system was intended to be a demonstration facility. Since its construction, it has served well in this regard. Over 3,000 visitors viewed the facility during the 1973 Illinois Land Improvement Contractors Conservation Show. Since then it has been visited by numerous groups of livestock producers, school children, other groups interested in water pollution control, and by many individuals seeking firsthand knowledge on the management and operation of runoff control systems.

Figure 30. Two examples of auxiliary settling basin screens.

The other producers, by the fact that they were pioneers in installing runoff control systems, report similar experiences. In every case, the facilities are visited periodically by organized groups such as extension tours, feed company tours, farm-city exchanges, conservation tours, and foreign visitor groups. In addition, most of the farmers report frequent visits by other farmers interested in installing similar systems and wanting to find out more about them firsthand. The cooperating farmers were furnished data obtained during this monitoring project, which often aided them in more effectively describing their systems. Project personnel from the University of Illinois Agricultural Engineering Department were occasionally invited to participate in these tours and describe the project and results. All of the farmers involved in the study took part in a University of Illinois telenet program in December, 1974, during which they described their systems and experiences to a state-wide audience.

The demonstration aspect of the study was very successful. The farmers were extremely cooperative and willing to give their time to meet with visitors and discuss their runoff control systems. The long-term benefits will be difficult to evaluate, but the attitude of visitors left no doubt that visiting the sites helped them a great deal in understanding and accepting runoff control measures.

FEEDLOT RUNOFF CONTROL PROGRAM - SUMMARY

The feedlot runoff control systems evaluated in this study were among the first installed in Illinois. All are of the more conventional, zero-discharge type meaning that under normal conditions, all runoff is collected and stored until final disposal by land application, rather than attempting to treat and discharge any of the runoff.

Cleaning the settling basin and dewatering the holding pond did not require excessive labor by the farmer. These management requirements are needed to keep the system operating properly. If the settling basin is not cleaned often enough, the outlet clogs and more solids carry through to the holding pond. If the pond is not dewatered on a timely basis, it may overflow and discharge. However, as even the small amount of management may be objectionable to some farmers, newer runoff control systems requiring even less management should be studied.

The systems studied were installed voluntarily, while in the future, conditions may force many otherwise unwilling farmers to install systems. If so, management is likely to be at a much lower level than with the systems observed. All of the systems studied effectively prevented feedlot runoff from polluting streams and rivers. In many cases, their installation also alleviated some other nuisance conditions in farmyards and nearby fields due to runoff and manure carried by runoff.

Some economic benefit can be realized from the application of the feedlot runoff water and the fertilizer nutrients it contains onto cropland. In most instances, such benefit is relatively small. However, on larger operations, the economic benefit from application of the fertilizer nutrients can be significant, and management of the runoff to insure maximum nutrient use may be advisable.

In summary, the systems studied provide effective, practical, and relatively economical means of controlling feedlot runoff in almost every farm situation. Their cost may be regarded as prohibitive in some instances, especially on some small open lots where capital investment in the feedlot itself is fairly low. Current research at the University of Illinois and

other locations indicates that on these small, open facilities, vegetative filter areas may control runoff with less cost and management than associated with holding ponds. These filter areas will not be adaptable to every farm, and until acceptable design criteria are developed, the proven, conventional systems described in this report can provide a satisfactory means of controlling feedlot runoff.

PROJECT PUBLICATIONS

Dickey, E. C. and D. H. Vanderholm. 1976. Performance of livestock feedlot runoff control systems. Illinois Research 18, No. 1:10-11.

Dickey, E. C. and D. H. Vanderholm. 1975. Water quality and management characteristics of feedlot runoff holding ponds. Paper No. 75-4568 presented at the 1975 Winter Meeting American Society of Agricultural Engineers, Chicago, IL.

Feedlot runoff control research program. 1975. Illinois Institute for Environmental Quality Document No. 75-12.

Vanderholm, D. H. and E. C. Dickey. 1976. Control of runoff from uncovered swine confinement facilities. Proc. Int. Pig Veterinary Soc. 1976 Congress, Ames, Iowa. (in press)

REFERENCES

Booram, C. V., R. J. Smith, and T. E. Hazen. 1973. Some chemical and physical aspects of phosphate precipitation from anaerobic liquors derived from animal waste lagoons. Paper No. 73-4522 presented at the 1973 Winter Meeting ASAE, Chicago, Illinois.

Braids, O. C. 1972. Land disposal management of livestock wastes. Proc. Illinois Livestock Management Conference. Agr. Engr. Dept., UIUC.

Bremner, J. M. and D. R. Keeney. 1965. Steam distillation of ammonium, nitrate, and nitrite. *Analytica Chemica Acta* 32:485-495.

Chang, A. C., W. R. Olmstead, J. B. Johanson, and G. Yamashita. 1974. The sealing mechanism of wastewater ponds. *Journal Water Pollution Control* 46, No. 7:1715-1721.

Gilbertson, C. B., J. R. Ellis, J. A. Nienaber, T. M. McCalla, and T. J. Klopfenstein. 1975. Properties of manure accumulations from midwest beef cattle feedlots. *Transactions of ASAE* 18, No. 2:327-330.

Gilbertson, C. B., T. M. McCalla, J. R. Ellis, O. E. Cross, and W. R. Woods. 1971. Runoff, solid wastes, and nitrate movement on beef feedlots. *Journal Water Pollution Control* 43, No. 3:483-493.

Horton, M. L., J. L. Halbeisen, J. L. Wiersma, A. C. Dittman, and R. M. Luther. Land disposal of beef wastes: climate, rates, salinity, and soil. 1975. Managing Livestock Wastes, Proc. 3rd Int. Symp. Livestock Wastes. ASAE PROC-275, 258-260.

Koelliker, J. K. and J. R. Miner. 1973. Desorption of ammonia from anaerobic lagoons. *Transactions of ASAE* 16, No. 1:148-151.

Livestock waste management with pollution control. 1975. North Central Regional Research Publication 222, Midwest Plan Service, Ames, Iowa.

Mathers, A. C. and B. A. Stewart. 1971. Crop production and soil analyses as affected by application of cattle feedlot waste. Proc. Int. Symp. Livestock Wastes, PROC-271, 229-231.

Mitchell, J. K. and E. C. Dickey. 1973. Device for obtaining water samples from small ponds or lagoons. *Transactions of ASAE* 16, No. 3:544-545.

Standard Methods for the Examination of Water and Wastewater. 1971. American Public Health Association. New York. 13th ed.

Swanson, N. P., L. N. Mielke, J. C. Lorimer, T. M. McCalla, and J. R. Ellis. 1971. Transport of pollutants from sloping cattle feedlots as affected by rainfall intensity, duration, and recurrence. Proc. Int. Symp. on Livestock Wastes, ASAE PROC-271.

Vanderholm, D. H., J. C. Lorimer, and S. W. Melvin. 1974. Field performance of selecting beef feedlot waste-handling systems. Paper No. 74-4015 presented at the 1974 Annual Meeting, ASAE, Stillwater, Oklahoma.